Appendix A
Other CEA MWCNT Prioritization Process Documents

Appendix A
Other CEA MWCNT Prioritization Process Documents

A.1 CEA MWCNT List of Influential Factors

For a given case study, some of the Comprehensive Environmental Assessment (CEA) Levels, Elements, and Risk Relevance Factors (RRFs) will be of elevated importance to understanding risk, and identifying these is part of the goal of the process. Another goal is to determine the rationale behind their stated importance. In this case study involving multiwalled carbon nanotubes (MWCNT), the Influential Factors (IFs) help identify the aspects of a particular portion of the CEA Framework that needs to be understood. These IFs include characteristics of (1) methods and techniques related to the material (i.e., MWCNT), (2) the material (i.e., MWCNT) and its characteristics, (3) surrounding environment which may influence the material's behavior, and within the previously mentioned categories, (4) the associated behaviors and relationships. Participants selected from a list of IFs unique to MWCNT indicate what aspects of the material may influence the potential risk associated with an Element-Risk Relevance Factor (E-RRF) pair.

The IFs and their definitions are customized for this particular MWCNT application of the CEA process, and are shown in **Table A-1**. The list of IFs and their definitions were provided to participants in a tab in the spreadsheet tool (see **Appendix K** for details related to the CEA MWCNT Prioritization Tool).

Table A-1. List of Influential Factors and Their Definitions

Influential Factor	Definition	Source
Methods and Techniques		
Analytical techniques	Instrumentation and methods used to characterize chemicals or the surrounding environment.	Tchobanoglous et al., 2003
Control technologies	Equipment, processes, or actions used to reduce pollution at its source.	U.S. EPA, 2012b

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
MWCNT processing methods	Methods to modify MWCNT after synthesis and before incorporation into a product. Examples include purification, functionalization, and dispersal in solvents.	U.S. EPA, 2012b, Section 2.2.3
MWCNT purity	A substance is said to be pure when its physical and chemical properties coincide with those previously established and recorded in the literature, and when no change in these properties occurs after application of the most selective fractionation techniques. The opposite, impurity—describes an unintended constituent present in a substance as produced. For nanomaterials (ENMs), purity is expressed as the percentage of the intended ENM present (e.g., 95% pure).	OECD, 2010
MWCNT synthesis methods	Methods to produce carbon nanotubes, including MWCNT. Examples include chemical vapor deposition, arc discharge, and laser ablation.	U.S. EPA, 2012b, Section 2.2.2
Personal protective equipment	Personal protective equipment, commonly referred to as PPE, is equipment worn to minimize exposure to a variety of hazards. Examples of PPE include such items as gloves, foot and eye protection, protective hearing devices (e.g., earplugs, muffs), hard hats, respirators, and full body suits.	OSHA, 2003
MWCNT Engineered Nanomaterials (ENM) Characteristics		
Absorption/desorption ability	The ability of a material to associate/dissociate on the surface of another material.	Sawyer et al., 2003
Aggregation/agglomeration state	A'/A", where A' is the effective cross-section of a primary particle and A" is the effective cross-section of an agglomerated/aggregated particle. According to current understanding, as particles agglomerate or aggregate, they form larger secondary particles. The increased size of these secondary particles might affect exposure. For example, if primary particles aggregate or agglomerate, the resulting secondary particles might not be able to enter a cell. In the draft case study document, the term "bundle" is used to subsume aggregates, agglomerates, and other clusters of MWCNT reported in the supporting literature because of the inconsistency in usage and, more importantly, the frequent lack of adequate information to determine which specific term might be more appropriately applied to a particular dispersion state observed in a study or report. Where possible, the case study describes the relative characteristics of different dispersion states (e.g., more loosely or tightly bundled, ropier or more entangled) and quantifies the differences between these characteristics if this information is provided by the study authors.	OECD, 2010
Applied coatings	The specific surface coating applied to a ENM that may alter its behavior. The addition of surface coatings (e.g., polymers) or other modification of materials by covalent or non-covalent attachment of new molecular components (i.e., functionalization).	Kohler et al., 2008; Ma et al., 2008; Hirsch and Vostrowsky, 2005

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
Biodegradability	The tendency of a material to undergo either complete mineralization to inorganic end products or partial transformation to an intermediate product through interaction with living organisms.	Sawyer et al., 2003
Catalytic activity	The ability of a material to change the rate of a chemical reaction by acting as a catalyst to participate in multiple transformations. Higher catalytic activity means more reactions can occur at the same time (e.g., due to higher surface area on the material).	Fukui et al., 2004
Charge	Electric charge present at an interface, for instance on the surface of a semiconductor material, or on the surface of a protein in water. Electric charge is a physical property of matter that causes it to experience a force when near other electrically charged matter. The electric charge is a fundamental conserved property of some subatomic particles, which determines their electromagnetic interaction. Electrically charged matter is influenced by, and produces, electromagnetic fields.	Wangsness, 1986
Conductive or magnetic properties	The manner and extent to which a material conducts electricity or imparts/reacts to magnetic fields.	Wangsness, 1986
Crystalline phase	The various distinct homogenous structures having uniform physical and chemical characteristics in which a single material may exist.	Callister, 2000
Lipophilicity	The ability of a material to dissolve in fats, oils, or other non-polar substances. A measure of a material’s likelihood to bioaccumulate, since lipophilic materials are more likely to reside in an organism’s lipid tissue. Lipophilicity can be measured using the octanol/water coefficient (Kow).	Wiesner and Bottero, 2007
Matrix bound vs. free	The term “free MWCNT” refers to pure, unbound materials. The term “matrix-bound MWCNT” refers to these materials as a part of a polymer matrix (e.g., the flame-retardant formulation).	U.S. EPA, 2012b, Chapter 2
Morphology (e.g., aspect ratio, length, width, shape)	Morphology includes aspects of the outward appearance (shape, structure, color, pattern). Note that morphology may not always be apparent from the outside for ENMs (e.g., the number of walls in a MWCNT).	Encyclopedia Britannica, 2012
Persistence	A material’s ability to resist degradation in the environment through chemical, biological, or photolytic processes. Often expressed as the chemical half-life of the material once released into the environment.	Vallero, 2004
Redox potential	A measure of the tendency of a chemical species to acquire electrons and thereby be reduced. Redox potential is measured in volts (V) or millivolts (mV). Substances more strongly electronegative than hydrogen have positive redox potentials. Substances less electronegative than hydrogen have negative redox potentials.	Onishi et al., 1960
Size/size distribution	The physical dimensions of a particle determined by specified measurement conditions and with a specified method. If a group of particles are of differing sizes, they may be described by a Particle Size Distribution.	OECD, 2010
Specific surface area	The surface area of a unit mass of the material.	OECD, 2010

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
Structural formula/molecular structure	The empirical formula and molecular structure describing the composition of the ENM.	OECD, 2010
Surface chemistry	Chemical nature, including composition, of the outermost layers of the nano-object.	OECD, 2010
Water solubility/dispersibility	Degree to which a material (the solute) can be dispersed in another material (the solvent) such that a single, temporally stable, phase results.	OECD, 2010
Environmental Conditions		
Surrounding Media		
Air	The mixture of gases comprising the Earth's atmosphere.	NOAA, 2009
Groundwater	(1) Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.	USGS, 2012
Sediment (aquatic)	Usually applied to material in suspension in water or recently deposited from suspension. In the plural, the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.	USGS, 2012
Soil (terrestrial)	All loose, unconsolidated earth and organic materials above bedrock that support plant growth.	USGS, 2012
Surface water	Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.	USGS, 2012
Wastewater	The combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments.	Tchobanoglous et al., 2003
Physical Conditions		
Flow regime	Encompasses the following characteristics of stream flow and their interactions: magnitude, timing, frequency, duration, and rate of change.	Clark, 1996
Light availability	The amount of light in the visible spectrum that is available to an environmental system.	Encyclopedia Britannica, 2012
Soil porosity	A measure of the void space in a soil. Porosity is measured as a fraction of the volume of voids over the total volume, between 0–1, or as a percentage between 0–100%	Dullien, 1992
Soil/sediment fractionation	A range of methods used to characterize the structure of a soil or sediment, which is based on the different elements in soil, such as content, structure, size, morphology, properties, and the interaction between them.	Colleuille and Braudeau, 1996

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
Temperature	A measure of the internal energy that a substance contains. Temperature is the most measured quantity in the atmosphere.	NOAA, 2009
Wind	The horizontal motion of the air past a given point. Winds begin with differences in air pressures. A pressure gradient across locations sets up a force pushing from the area of high pressure toward the area of low pressure. The greater the difference in pressures, the stronger the force. The distance between the area of high pressure and the area of low pressure also determines how fast the moving air is accelerated. Meteorologists refer to the force that starts the wind flowing as the "pressure gradient force." High and low pressure are relative. There is no set number that divides high and low pressure. Wind is used to describe the prevailing direction from which the wind is blowing with the speed given usually in miles per hour or knots.	NOAA, 2009
Chemical Conditions		
Conductivity	A measure of the ability of a solution to conduct an electrical current. Serves as a surrogate measure of the total dissolved solids concentration of the water, expressed as deci-siemens per meter (dS/m) or mmho/cm.	Tchobanoglous et al., 2003
Dispersing agents	Either a non-surface active polymer or a surface-active substance added to a suspension, usually a colloid, to improve the separation of particles and to prevent settling or clumping. Dispersants normally consist of one or more surfactants, but may also be gases.	OECD, 2010
Dissolved oxygen content	The concentration of oxygen gas dissolved in water.	Sawyer et al. 2003
Exposure to sunlight	The direct application of sunlight to a system or material.	Encyclopedia Britannica, 2012
Heavy metals in environment	The presence of heavy metals in the air, water, or soils in the environment.	Encyclopedia Britannica, 2012
Ionic strength in environment	The ionic strength of a solution is a measure of the concentration of dissolved chemical constituents in that solution; "solution" in this context may pertain to a variety of surrounding environmental media (e.g., soil, water environments).	Encyclopedia Britannica, 2012
Ligand concentrations in environment	The concentration of ions or molecules in the environment that can bond to a target central molecule to form a coordination complex.	Cotton et al., 1999
Natural organic matter (NOM)	The organic component of the soil consisting of living organisms, dry plants, and residues of animal origin. Per mass unit, this organic component is the most chemically active component of the soil. This component stores several essential elements, stimulates the proper structure of the soil, regulates pH changes as it is a source with capacity for the exchange of cations, supports the relationship between air and water in the soil, and is a huge geochemical store of carbon.	U.S. EPA, 2010a
Other contaminants in environment	Chemicals or materials, naturally occurring or anthropogenic that are present in a particular environment in addition to the constituent of concern (MWCNT for this case study). These chemicals or materials may potentially interact with the constituent of concern in some way.	Encyclopedia Britannica, 2012

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
pH	The negative logarithm of the hydrogen-ion concentration of water.	Tchobanoglous et al. 2003
Protein concentration in environment	The concentration of proteins in the air, water, or soils.	No source available*
Salinity	A surrogate measure of the total dissolved solids concentration in water. Salinity is determined by measuring the electrical conductivity.	Tchobanoglous et al. 2003
Surfactant (in laboratory)	A substance that exhibits some superficial or interfacial activity. Can be categorized as anionic, cationic, or nonionic.	Salager, 2002
Biological Conditions		
ADME	Acronym for absorption, distribution, metabolism, and excretion.	OECD, 2010
Bioaccumulation	The process by which an organism takes a chemical into the body through all exposure routes and dilutes the chemical through excretion, metabolism, and growth, but accumulates a net “body burden” of the chemical	Environment Canada, 2010; U.S. EPA, 2010b
Biomagnification	The process by which a chemical increases in concentration in tissues as it moves up trophic levels in an ecosystem.	U.S. EPA, 2012c
Microbial communities in environment	A consortium of microorganisms in the environment, which may include bacteria, protozoa, fungi, rotifers, and algae.	Tchobanoglous et al., 2003
Organism health	A measure of an organism’s ability to function normally in all aspects of its life cycle and development.	Encyclopedia Britannica, 2012
Species/individual developmental behavior	The actions, habits, and choices of a species or individual during growth and maturation.	Encyclopedia Britannica, 2012
Species/individual feeding behavior	The actions, habits, and choices of a species or individual pertaining to the gathering and consumption of food.	Encyclopedia Britannica, 2012
Species/individual reproductive behavior	The actions, habits, and choices of a species or individual pertaining to their reproductive behavior.	Encyclopedia Britannica, 2012
Social Conditions		
Acute exposure	Exposure by the oral, dermal, or inhalation route for 24 hours or less.	U.S. EPA, 2010b
Chronic exposure	Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species).	U.S. EPA, 2010b

Table A-1. List of Influential Factors and Their Definitions (continued)

Influential Factor	Definition	Source
Exposure route	The route a substance takes from its source (where it began) to its end point (where it ends), and how organisms come into contact with it.	ATSDR, 2009
Geographic location (i.e., rural vs. urban)	The general setting of the system of interest, such as a rural or urban location.	Encyclopedia Britannica, 2012
Habitat structure	The composition and arrangement of physical matter at a location, used as the living area for one or more species.	Byrne, 2007
Human activity	All physical, social, and economic activity that human individuals or populations undertake.	No source available*
Individual activity level	A measure of the physical activity exerted by an individual (e.g., sitting vs. exercising).	No source available*
Life stage	A specific stage along the continuum of an organism's life cycle.	Encyclopedia Britannica, 2012
Social Conditions (continued)		
Occupation	A job or profession. A way of spending time.	No source available*
Subchronic exposure (Intermediate exposure)	Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately 90 days in typically used laboratory animal species).	U.S. EPA, 2010b
Susceptible populations/individuals	Susceptibility may be defined as "individual- and population-level characteristics that increase the risk of health effects in a population, including, but not limited to, genetic background, birth outcomes (e.g., low birth weight, birth defects), race, sex, life stage, lifestyle (e.g., smoking status, nutrition), preexisting disease, socioeconomic status (e.g., educational attainment, reduced access to health care), and characteristics that may modify exposure (e.g., time spent outdoors)."	Sacks et al., 2011

* For those references for which no source was available (noted as "no source available"), experts in the field were consulted to provide definitions.

A.2 Final Workshop Agenda

The face-to-face workshop was held October 29–31, 2012 at the Environmental Protection Agency (EPA) in Research Triangle Park (109 T.W. Alexander Drive, Durham, NC, 27711, Auditorium C111). The final agenda for the workshop is shown in **Table A-2**.

Table A-2. Final Workshop Agenda for "Nanomaterial Case Study Workshop Process: Identifying and Prioritizing Research for Multiwalled Carbon Nanotubes" held October 29–31, 2012 at EPA-RTP.

October 29th	8:00 – 8:30	Breakfast Opportunity at EPA
	8:30 –10:30	EPA Public Information Exchange Meeting[1]
	10:30 – 11:00	Break
	11:00 – 11:15	RTI Welcome*
	11:15 – 12:00	Review Prioritization Scores to Date*
	12:00 – 12:45	Lunch
	1:00 – 1:15	Nominal Group Technique (NGT) Instructions*
	1:15 – 3:00	NGT Process*
	3:00 – 3:30	Break
	3:30 – 5:00	Final Round Scoring
	5:00 – 5:30	Demonstration of CEA Pilot Project*
	5:30	Adjourn
	5:30 – 5:45	Shuttle to Hotel
	6:30 – 8:30	Dinner Opportunity
October 30th	8:00 – 8:30	Breakfast Opportunity at EPA
	8:30 – 9:00	Feedback from Participants on Process
	9:00 – 10:00	Review of Prioritization Results from Day 1*
	10:00 – 10:30	Break
	10:30 – 11:15	Introduce Goals of Research Question Development*
	11:15 – 11:30	Form Breakout Groups*
	11:30 – 1:00	Lunch
	1:00 – 3:00	Breakout Group Work
	3:00 – 3:20	Break
	3:20 – 5:30	Breakout Group Work
	5:30	Adjourn
	5:30 – 5:45	Shuttle to Hotel
	6:30 – 8:30	Dinner Opportunity

[1] The Public Information Exchange Meeting was separate from the RTI workshop, which was funded by EPA and conducted independently by RTI International, in compliance with the Federal Advisory Committee Act. As stated in a Federal Registrar Notice published on July 2, 2012 (http://www.gpo.gov/fdsys/pkg/FR-2012-07-02/html/2012-16137.htm), the EPA Public Information Exchange Meeting provided an opportunity for the public to ask questions about the current application of CEA to MWCNT.

Table A-2. Final Workshop Agenda for "Nanomaterial Case Study Workshop Process: Identifying and Prioritizing Research for Multiwalled Carbon Nanotubes" held October 29–31, 2012 at EPA-RTP. (continued)

October 31st	8:30 – 9:00	Breakfast Opportunity at EPA
	9:00 – 10:30	Breakout Group Reports*
	10:30 – 11:00	Break
	11:00 – 12:00	Breakout Group Reports Continue*
	12:00 – 12:15	Wrap Up and Adjourn
	12:15 – 1:00	RTI and EPA Available for Comments and Critiques

*Agenda items with corresponding presentation slides (see **Appendix L**).

A.3 Appendix A References

ATSDR (Agency for Toxic Substances and Disease Registry). (2009). Glossary of Terms. Available online at http://www.atsdr.cdc.gov/glossary.html

Byrne, LB. (2007). Habitat structure: A fundamental concept and framework for urban soil ecology. Urban Ecosyst 10: 255-274. http://dx.doi.org/10.1007/s11252-007-0027-6

Callister Jr., WD. (2000). Materials Science and Engineering An Introduction. New York: John Wiley and Sons.

Clark, MM. (1996). Transport Modeling for Environmental Engineers and Scientists. New York: John Wiley and Sons.

Colleuille, H; Braudeau, E. (1996). A soil fractionation related to soil structural behaviour. Aust J Soil Res 34: 653. http://dx.doi.org/10.1071/SR9960653

Cotton, FA; Wilkinson, G; Murillo, CA. (1999). Advanced Inorganic Chemistry. New York: John Wiley and Sons.

Dullien, FAL. (1992). Porous media : fluid transport and pore structure. San Diego: Academic Press.

Encyclopedia Britannica Online; Villee, CA; Pallardy, R; Rafferty, JP. (2012). Morphology [Encyclopedia]. In Encyclopedia Britannica Online. Chicago, IL: Encyclopædia Britannica, Inc. http://www.britannica.com/EBchecked/topic/392797/morphology

Environment Canada. (2010). DSL categorization under CEPA 1999 section 73: Ecological categorization criteria and process.

Fukui, T; Murata, K; Ohara, S; Abe, H; Naito, M; Nogi, K. (2004). Morphology control of Ni–YSZ cermet anode for lower temperature operation of SOFCs. J Power Sourc 125: 17-21. http://dx.doi.org/10.1016/S0378-7753(03)00817-6

Hirsch, A; Vostrowsky, O. (2005). Functionalization of carbon nanotubes. Top Curr Chem 245: 193-237. http://dx.doi.org/10.1007/b98169

Köhler, A; Som, C; Helland, A; Gottschalk, F. (2008). Studying the potential release of carbon nanotubes throughout the application life cycle. J Clean Prod 16: 927-937. http://dx.doi.org/10.1016/j.jclepro.2007.04.007

Ma, HY; Tong, LF; Xu, ZB; Fang, ZP. (2008). Functionalizing carbon nanotubes by grafting on intumescent flame retardant: Nanocomposite synthesis, morphology, rheology, and flammability. Adv Funct Mater 18: 414-421. http://dx.doi.org/10.1002/adfm.200700677

NOAA (National Oceanic and Atmospheric Administration). (2009). National weather service glossary. Available online at http://w1.weather.gov/glossary/

OECD (Organisation for Economic Co-operation and Development). (2010). Preliminary guidance notes on sample preparation and dosimetry for the safety testing of manufactured nanomaterials [OECD SIDS]. Paris, Fr.

Onishi, J; Kondo, W; Uchiyama, Y. (1960). Preliminary report on the oxidation-reduction potential obtained on surfaces of gingiva and tongue and in interdental space. Bull Tokyo Med Dent Univ 7: 161.

OSHA (Occupational Safety & Health Administration). (2003). Personal protective equipment. Publication # OSHA 3151-12R. www.osha.gov/Publications/osha3151.pdf

Sacks, JD; Stanek, LW; Luben, TJ; Johns, DO; Buckley, BJ; Brown, JS; Ross, M. (2011). Particulate-matter induced health effects: Who is susceptible? Environ Health Perspect 119: 446-454. http://dx.doi.org/10.1289/ehp.1002255

Salager, JL. (2002). Surfactants types and uses. Laboratory of formulation, interfaces, reheology, and processes. Universidad de los Andes. Salager, JL.

Sawyer, CN; McCarty, PL; Parkin, GF. (2003). Chemistry for environmental engineering and science (5th ed.). Boston, MA: McGraw-Hill.

Tchobanoglous, G; Burton, FL; Stensel, HD. (2003). Wastewater engineering: Treatment and reuse. In th (Ed.), (9780070418783 ed.). Boston, MA: McGraw-Hill.

U.S. EPA (U.S. Environmental Protection Agency). Terms and Acroynms Finder. Available online at http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do

U.S. EPA (U.S. Environmental Protection Agency). (2010a). Nanomaterial case studies workshop: Developing a comprehensive environmental assessment research strategy for nanoscale titanium dioxide [EPA Report]. (EPA/600/R-10/042). Research Triangle Park, NC.

U.S. EPA (U.S. Environmental Protection Agency). (2010b). Nanomaterial case studies: Nanoscale titanium dioxide in water treatment and topical sunscreen (final) [EPA Report]. (EPA/600/R-09/057F). Research Triangle Park.

U.S. EPA (U.S. Environmental Protection Agency). (2012a). Comprehensive environmental assessment: A meta-assessment approach to increase effectiveness of risk management and research planning [Fact Sheet]. Research Triangle Park, NC: http://www.epa.gov/nanoscience/files/CEAPrecis.pdf. U.S. Environmental Protection Agency. http://www.epa.gov/nanoscience/files/CEAPrecis.pdf

U.S. EPA (U.S. Environmental Protection Agency). (2012b). Nanomaterial case study: a comparison of multiwalled carbon nanotube and decabromodiphenyl ether flame-retardant coatings applied to upholstery textiles (draft) [EPA Report]. (EPA/600/R-12/043A). RTP, NC.

U.S. EPA (U.S. Environmental Protection Agency). (2012c). Nanomaterial case study: Nanoscale silver in disinfectant spray (final report) [EPA Report]. (EPA/600/R-10/081F). Washington, DC.

USGS (U.S. Geological Survey). (2012). Water Science Glosary of Terms. Available online at ga.water.usgs.gov/edu/dictionary.html

Vallero, DA. (2004). Environmental contaminants: assessment and control. Amsterdam, The Netherlands: Elsevier Academic Press.

Villee, CA; Pallardy, R; Rafferty, JP. (2012). Morphology [Encyclopedia]. In Encyclopedia Britannica Online. Chicago, IL: Encyclopædia Britannica, Inc. http://www.britannica.com/EBchecked/topic/392797/morphology

Wangsness, R. (1986). Electromagnetic fields. New York: Wiley.

Wiesner, MR; Bottero, J, -Y. (2007). Environmental nanotechnology: Applications and impacts of nanomaterials. New York: McGraw-Hill.

Appendix B
Participants in the CEA MWCNT Prioritization Process

Appendix B
Participants in the CEA MWCNT Prioritization Process

B.1 Participants in the Collective Group: Rounds 1 and 2

When determining who to invite to participate in the first two rounds of prioritization, a Web search was performed. We aimed to invite participants (both domestic and international) who represented a broad range of expertise, including areas of manufacturing, policy, ecological effects, risk assessment, environmental fate and transport, exposure and dose, material characterization, life cycle assessment, and human health effects. A diverse representation of sector perspectives was also targeted, including industry, academia, government, and non-government organizations (NGOs). More than 200 experts were identified as potential participants for the prioritization process. Participants were then invited to participate in several iterations of invitations. **Figure 6** in previous sections shows an overview of the distribution of participants across sectors and areas of expertise in all three prioritization rounds. In addition to this overview, **Table B-1** shows the final number of participants by stakeholder group and area of expertise from Round 2 (N_{Round2}= 28 participants). Because only three participants from Round 1 (N_{Round1}= 31 participants) chose not to participate in Round 2, these numbers are shown only for Round 2 rather than for both Rounds 1 and 2 for reasons of brevity. However, **Table B-2** provides a full list of participants from both Rounds 1 and 2, along with their sector and areas of expertise. **Figure 6** in previous sections provides an overview of participant distributions across sectors and areas of expertise for all three rounds. Furthermore, more detailed information on the participants who participated in the face-to-face workshop is also provided in subsequent sections (see **Appendix B.2**).

Table B-1. Total number of participants distributed across sectors and areas of expertise from Round 2

Area of Expertise	Government	Industry	NGO	Academic Institutions & Centers	Independent Consultants	Total
Manufacturing		1				1
Policy	1			1		2
Ecological Effects	1			3	1	5
Risk Assessment	1	1				2
Environmental Fate & Transport	1			1		2
Exposure & Dose	2			2		4
Material Characterization	2			3		5
Human Health Effects	2	1	1	1	2	7
Total	**10**	**3**	**1**	**11**	**3**	**28**

Table B-2. Round 1 and Round 2 participants with associated affiliations, fields of expertise, and assigned sector groups (continued)

Last Name	First Name	Affiliation	Field of Expertise (in CEA Terms)	Sector Group
Alwood	Jim	EPA	Policy	Government
Bang	John	North Carolina Central University	Exposure & Dose	Academic Institutions & Centers
Bates	Matthew	U.S. Army Corp of Engineers	Risk Assessment	Government
Bonner	James	North Carolina State University	Human Health Effects	Academic Institutions & Centers
Coleman	Jessica	U.S. Army Corp of Engineers	Environmental Fate & Transport	Government
Dahm	Matthew	Centers for Disease Control and Prevention	Exposure & Dose	Government
Ensor	David	RTI International	Human Health Effects	Independent Consultants
Fifield	Leo	Pacific Northwest National Laboratory	Material Characterization	Government
Green	Micah	Texas Tech University	Material Characterization	Academic Institutions & Centers
Hansen	Steffen Foss	Technical University of Denmark	Policy	Academic Institutions & Centers
Henry	Carol	Retired from American Chemistry Council; also formerly with California EPA; George Washington University	Human Health Effects	Independent Consultants
Illuminato	Ian	Friends of the Earth	Human Health Effects	NGO
Kapustka	Larry	LK Consultancy, Calgary, Alberta	Ecological Effects	Independent Consultants
Klaine	Stephen	Clemson University	Ecological Effects	Academic Institutions & Centers
Klaper	Rebecca	School of Freshwater Sciences	Ecological Effects	Academic Institutions & Centers
Lander	Debbie	DuPont	Risk Assessment	Industry
Liu	Jie	Duke University and Unidym Advisory Board	Manufacturing	Industry
Mansfield	Elisabeth	NIST	Material Characterization	Government
Sepulveda	Maria	Purdue University	Ecological Effects	Academic Institutions & Centers
Marquis	Bryce	University of Central Arkansas	Material Characterization	Academic Institutions & Centers
Morgan	Alexander	University of Dayton Research Institute	Material Characterization	Academic Institutions & Centers
O'Connor	Brian	FPInnovations-PAPRICAN	Human Health Effects	Industry
Petersen	Elijah	NIST	Ecological Effects	Government

Table B-2. Round 1 and Round 2 participants with associated affiliations, fields of expertise, and assigned sector groups (continued)

Last Name	First Name	Affiliation	Field of Expertise (CEA Terms)	Stakeholder Group
Poland	Craig	Institute of Occupational Medicine (UK)	Human Health Effects	Government
Ramachandran	Gurumurthy	University of Minnesota, School of Public Health, Division of Environmental Health Sciences	Exposure & Dose	Academic Institutions & Centers
Thrall	Brian	Pacific Northwest National Laboratory	Human Health Effects	Government
Westerhoff	Paul	Arizona State University	Environmental Fate & Transport	Academic Institutions & Centers
Zumwalde	Ralph	NIOSH	Exposure & Dose	Government

B.2 Subset of Participants in the Face-to-Face Workshop

As described in **Section 2.5**, participants were selected to attend the face-to-face workshop based on the priority areas that emerged from the second round of prioritization. Specifically, the Element-Risk Relevant Factor (E-RRF) pairs that were assigned to red and orange boxes of the Prioritization Matrix at the close of Round 2 determined who among the larger pool of participants were invited to attend the face-to-face workshop. Each area of expertise corresponded to various areas of the Comprehensive Environmental Assessment (CEA) Framework; essentially, the percentage of each expertise area was proportional to the percentage of the 25 spots at the workshop attendees with that expertise, with the exception of expertise areas considered pertinent to all Levels of the CEA Framework, as explained in the next section. An even distribution across sectors was also a priority in selecting workshop attendees, although even distribution was done in proportion to the percentage of each expertise area (see **Table B-3**).

Table B-3. Selection of participants for workshop attendance based on CEA Level, areas of expertise, and assigned sector groups

CEA Level	Target %	Target No.	Selected No.
Product Life Cycle	24%	4	1
Env TT&F	32%	5	2
Exposure Route	8%	1	1
Dose (Kinetics)	18%	3	3
Impacts	18%	3	10
Total	100%	17	17

Expertise Area	Chosen/Total Participants (No.)
Ecological Effects	5/5
Env TT&F	2/2
Exposure % Dose	4/4
Human Health Effects	5/7
Manufacturing	1/1
Material Characterization	5/5
Policy	1/2
Risk Assessment	2/2

Sector Area	Chosen/Total Participants (No.)
Academic Institutions and Universities	9/10
Government	9/11
Independent Consultants	3/3
Industry	3/3
NGOs	1/1

As explained previously, participants in this process represented expertise areas of ecological effects, environmental fate and transport, exposure and dose, human health effects, life cycle assessment, manufacturing, material characterization, policy, and risk assessment. Though many of these areas of expertise pertained to multiple areas of the CEA Framework, some of the areas of expertise were particularly well aligned with particular areas and represent very targeted subject matter expertise about specific research areas within the CEA detailed Framework. The expertise areas of policy, risk assessment, and material characterization were pertinent regardless of which E-RRFs were most prioritized during the prioritization rounds. Therefore, at least two individuals, and preferably three, were targeted to represent each of these areas of expertise at the workshop (however, it should be noted that only one participant within policy was finally invited due to the availability of participants within this area). The remaining expertise areas were all very closely aligned with CEA levels: Manufacturing and Life Cycle Assessment was aligned with Product Life Cycle and "Other" impacts, Environmental Fate and Transport was aligned with the CEA level of the same name, Exposure and Dose was aligned with the Exposure Route level and the Dose (Kinetics) level, and Ecological Effects and Human Health Effects were both aligned with Impacts.

After eight participants were selected to represent the broadly applicable expertise areas, the remaining 17 spots were divided between the specialized areas of expertise and sector representation. The percentage of the E-RRF pairs in the red and orange boxes of the prioritization matrix that map to a given CEA Level determined the number of participants with corresponding expertise who were invited to attend the face-to-face workshop. It should be noted that while these methods were used to select the individuals invited to participate in the face-to-face workshop, there were also other factors that influenced whether a participant was actually able to attend the workshop, including the fact that the Environmental Protection Agency (EPA) was only able to cover travel costs for one federal employee and unforeseen circumstances (e.g., budget, illness, and inclement weather).

B.2.1 Final List of Workshop Participants

There were a total of 13 participants who attended the face-to-face workshop. These participants represented a diverse range of sectors and areas of expertise (see **Figure 6** in previous sections). The final list of participants who attended the workshop is shown in **Table B-4**.

Table B-4. Final list of participants who attended the workshop, held October 29–31, 2012 at EPA in Research Triangle Park, NC

Last Name	First Name	Affiliation	Stakeholder Group
Bang	John	North Carolina Central University	Academic Institutions & Centers
Bonner	James	North Carolina State University	Academic Institutions & Centers
Coleman	Jessica	U.S. Army Corp of Engineers	Government
Ensor	David	RTI International	Independent Consultants
Illuminato	Ian	Friends of the Earth	NGO
Kapustka	Larry	LK Consultancy, Calgary, Alberta	Independent Consultants

Table B-4. Final list of participants who attended the workshop, held October 29–31, 2012 at EPA in Research Triangle Park, NC (continued)

Last Name	First Name	Affiliation	Stakeholder Group
Klaine	Stephen	Clemson University	Academic Institutions & Centers
Lander	Debbie	DuPont	Industry
Liu	Jie	Duke University and Unidym Advisory Board	Industry
Marquis	Bryce	University of Central Arkansas	Academic Institutions & Centers
O'Connor	Brian	FPInnovations-PAPRICAN	Industry
Petersen	Elijah	National Institute of Standards and Technology (NIST)	Government
Westerhoff	Paul	Arizona State University	Academic Institutions & Centers

B.3 Observers

In order to maintain the transparency of the process, outside public observers were invited to attend the 3-day face-to-face workshop[1]. We aimed to invite observers who represented a broad range of expertise and sectors. Because funding for travel would not be extended to potential observers, many invitees were from local institutions and universities (e.g., North Carolina State University, Center for Environmental Implications of NanoTechnology at Duke University) to ensure more observers at the workshop. During the workshop, observers were able to listen to the overview of the prioritization scores from the online rounds and watch the proceedings as the participants use the Nominal Group Technique (NGT) Round Robin to propose highest priority E-RRF pairs in round robin fashion within a specified time limit and complete a final round of scoring. On Day 2 of the workshop, observers listened to (1) feedback from participants about the CEA prioritization process, (2) the results from the previous day’s prioritization round, and (3) guidance to participants for generating breakout group reports. Observers were then dismissed for the remainder of the day to allow participants to focus on breakout group work. On Day 3, the public was invited to observe each breakout group present its research questions and risk management/risk decision implication reports formulated during Day 2 breakout group activities.

Table B-5. List of observers who attended the workshop, held October 29–31, 2012 at EPA in Research Triangle Park, NC

Last Name	First Name	Affiliation	Stakeholder Group
Baldauf	Richard	EPA/ORD/NRMRL	Government
Boyes	Will	EPA/ORD/NHEERL	Government

[1] A Federal Registrar Notice was issued along with the external review draft of the case study document to notify the public of the opportunity to observe the face-to-face workshop (see http://www.gpo.gov/fdsys/pkg/FR-2012-07-02/html/2012-16137.htm).

Table B-5. List of observers who attended the workshop, held October 29–31, 2012 at EPA in Research Triangle Park, NC (continued)

Last Name	First Name	Affiliation	Stakeholder Group
Burgoon	Lyle	EPA/ORD/NCEA	Government
Davis	Mike	EPA-retired/Independent Consultant	Government-retired/Independent Consultants
Doorn	Stacy	RTI International	Independent Consultants
Fedak	Kristen	ICF International	Independent Consultants
Gift	Jeff	EPA/ORD/NCEA	Government
Gillespie	Patricia	EPA/ORD/NCEA	Government
Hamernik	Karen	EPA/OCSPP/IO	Government
Harris	Adeline	ICF International	Independent Consultants
Lassiter	Meredith	EPA/ORD/NCEA	Government
Lehmann	Geniece	EPA/ORD/NCEA	Government
Long	Tom	EPA/ORD/NCEA	Government
McPhail	Robert	EPA	Government
Meacham	Connie	EPA/ORD/NCEA	Government
Sams	Reeder	EPA	Government
Vandenberg	John	EPA/ORD/NCEA	Government
Wang	Amy	EPA/ORD/NCCT	Government
Zepp	Richard	EPA/ORD/NERL	Government

B.4 CEA MWCNT Prioritization Workshop Evaluation Form

On Day 3 of the workshop, participants were asked to fill out the following CEA MWCNT Prioritization Workshop Evaluation Form. Twelve of the 13 participants returned a completed form. A detailed table of anonymous responses to each question is provided in **Table B-6**, and summary statistics for questions with numeric responses are provided in **Table B-7**.

1. With what type of organization are you affiliated (check as many as apply)?
   - a. ☐ Regulated facility or business
   - b. ☐ Industry sector
   - c. ☐ Consulting Company
   - d. ☐ Government
   - e. ☐ Trade association
   - f. ☐ Nonprofit Organization
   - g. ☐ School or University
   - h. ☐ Other ______________

OPTIONAL: Job Title: ____

OPTIONAL: Please provide your name/phone/email if we can contact you for questions about your responses.

EFFECTIVE COMMUNICATION/ CLARITY OF INFORMATION

On a scale of 1 to 5, where 1 is very unsatisfied and 6 is very satisfied, please indicate your level of satisfaction with the communication regarding the CEA MWCNT Prioritization Process

2. a. What was your experience regarding access to information about the expectations and methods for carrying out the <u>online</u>, pre-workshop portions of the CEA MWCNT Prioritization Process (*i.e., webinar, CEA nanocarbon website resources, and communication*)?
   - ☐ 6 very satisfied
   - ☐ 5 Satisfied
   - ☐ 4 Somewhat satisfied
   - ☐ Don't know
   - ☐ 3 Somewhat dissatisfied
   - ☐ 2 Dissatisfied
   - ☐ 1 Very dissatisfied

   b. COMMENT:____

3. a. What was your experience regarding the understandability of the CEA MWCNT Prioritization Process itself (*i.e., the effectiveness of the spreadsheet tool, the CEA Detailed Framework, and Influential Factors list to convey the information in a way that was easy to grasp and comprehend*)?
   - ☐ 6 very satisfied
   - ☐ 5 Satisfied
   - ☐ 4 Somewhat satisfied
   - ☐ Don't know
   - ☐ 3 Somewhat dissatisfied
   - ☐ 2 Dissatisfied
   - ☐ 1 Very dissatisfied

   b. COMMENT:____

4. a. What was your experience regarding access to information about the expectations and methods for carrying out the <u>in-person,</u> workshop portions of the CEA MWCNT Prioritization Process (*i.e., presentations on NGT, Round 3 prioritization, and breakout group activities*)?
   - ☐ 6 very satisfied
   - ☐ 5 Satisfied
   - ☐ 4 Somewhat satisfied
   - ☐ Don't know
   - ☐ 3 Somewhat dissatisfied
   - ☐ 2 Dissatisfied
   - ☐ 1 Very dissatisfied

   b. COMMENT:____

UTILITY OF THE PRIORITIZATION PROCESS STEPS

5. Please rate the steps of the Prioritization Process as to how useful they were in shaping your ultimate views of the most important priority areas on which to focus future research, with 6 = Very Useful and 1= Not Useful.

	Prioritization Step	Very Useful					Not Useful
1.	Reading Case Study	6	5	4	3	2	1
2.	Round 1 Prioritization.	6	5	4	3	2	1
3.	Reviewing Round 1 Results Independently	6	5	4	3	2	1
4.	Round 2 Prioritization	6	5	4	3	2	1
5.	NGT Discussion of Priority E-RRFS	6	5	4	3	2	1
6.	Round 3 Prioritization	6	5	4	3	2	1

6. What would you add/subtract/change about this process to increase your satisfaction?

____
____
____
____
____

WORKSHOP OUTPUTS

On a scale of 1 to 6, where 1 is very unsatisfied and 6 is very satisfied, please indicate your level of satisfaction with the outputs of the CEA MWCNT Prioritization Process

7. a. How satisfied are you that the outputs of this workshop included detailed, actionable research questions that, if pursued, would enable assessment and subsequent management of MWCNT risks?

☐ 6 very satisfied ☐ 3 Somewhat dissatisfied
☐ 5 Satisfied ☐ 2 Dissatisfied
☐ 4 Somewhat satisfied ☐ 1 Very dissatisfied
☐ Don't know

b. COMMENT:____

8. a. How satisfied are you that the outputs of this workshop linked the recommended research to the risk assessment and risk management actions the research would support?

☐ 6 very satisfied ☐ 3 Somewhat dissatisfied
☐ 5 Satisfied ☐ 2 Dissatisfied
☐ 4 Somewhat satisfied ☐ 1 Very dissatisfied
☐ Don't know

b. COMMENT:____

9. What would you add/subtract/change about the work products of this workshop to improve your satisfaction?

____
____
____
____
____

10. a. Would you recommend this workshop to others? Yes No

b. Why or why not? ____

Please give completed form to the workshop organizers or fax to Khara Grieger, RTI, 919-541-7243. Thank you!

B.5 Participant Responses to CEA MWCNT Prioritization Workshop Evaluation Form

The following table contains participants' responses to the CEA MWCNT Prioritization Workshop Evaluation Form (see **Section B.4**).

Table B-6. Participant responses to CEA MWCNT Prioritization Workshop Evaluation Form

Participant ID	Question 1 (Letter)	Question 1 (Text)	Question 1 – Job Title (optional)	Question 2a (#)	Question 2a (Text)	Question 2b
1	f	Nonprofit Organization	Health and Environment Campaigner	5	Satisfied	
2	b	Industry Sector	Program Manager - Environment and Sustainability	6	Very satisfied	
3	c	Consulting Company		6	Very satisfied	The Web site was not intuitive and took some poking around.
4	g	School or University	Professor	6	Very satisfied	
5	b	Industry Sector	Sr. Risk Assessor	5	Satisfied	
6	g	School or University	Associate Professor	5	Satisfied	
7	g	School or University	Professor	5	Satisfied	Tedious spreadsheet.
8	g	School or University	Assistant Professor	5	Satisfied	
9	g	School or University	Professor	3	Somewhat dissatisfied	
10	d	Government	Research Scientist	6	Very satisfied	
11	d	Government	Research Biologist	5	Satisfied	The Webinar and Web site were very helpful and informative.
12	c	Consulting Company	Senior Ecologist, Risk Assessor	5	Satisfied	There was some ambiguity about the value of the second round of the spreadsheet.

Participant ID	Question 3a (#)	Question 3a (Text)	Question 3b	Question 4a (#)	Question 4a (Text)	Question 4b
1	3	Somewhat dissatisfied	My dissatisfaction is based on the spreadsheet tool, which may not cater to all stakeholders.	5	Satisfied	
2	5	Satisfied		6	Very satisfied	
3	5	Satisfied		5	Satisfied	Good meeting.
4	6	Very satisfied		6	Very satisfied	
5	5	Satisfied		4	Somewhat satisfied	Should remind participants to review document before coming! I felt I did not do my best as I could not remember it all, so I was influenced by the speakers.
6	5	Satisfied		5	Satisfied	
7	5	Satisfied		6	Very satisfied	
8	5	Satisfied		6	Very satisfied	
9	4	Somewhat satisfied		6	Very satisfied	
10	3	Somewhat dissatisfied	Some parts were clear and others unclear (i.e., abiotic effects).	6	Very satisfied	The facilitators did an excellent job.
11	4	Somewhat satisfied	The spreadsheet was somewhat cumbersome and not very user-friendly.	6	Very satisfied	The NGT presentations were very helpful as well as the breakout groups.
12	3	Somewhat dissatisfied	The spreadsheet was brutal; many of the influential factors were irrelevant and the list was endless.	5	Satisfied	The NGT worked very well; the third round was unnecessary, ambiguous, and disconnected to the progress of the NGT.

Participant ID	Question 5(1)	Question 5(2)	Question 5(3)	Question 5(4)	Question 5(5)	Question 5(6)	Question 6
1	5	2	3	3	4	4	More NGT, better incorporated “other” category to show equal value among other potential priorities—also include in scope of case study.
2	6	6	4	4	6	2	The influence factors took a fair amount of time but were not really used or discussed to any extent. Perhaps the handling of these could be changed or else just done at the last stage of prioritization.
3	5	6	6	6	6	5	
4	5	4	5	5	6	6	A section that holds information about rationale for outliers.
5	6	5	4	4	5	4	More discussion time during #5.
6	6	5	6	5	6	2	Delete Round 3 prioritization.
7	5	5	5	5	5	6	New Web tool.
8	6	5	5	6	6	4	I would like "other" influential factors to be incorporated into further rounds of prioritization. Also, I think "why" could be re-communicated during result reviews.
9	6	3	4	3	5	5	
10	6	5	4	3	5	5	Time to read case study between NGT rounds or before it. I am less confident about my Round 3 results as compared to 2, but 3 was supposed to be the most definitive.
11	6	5	5	5	6	4	Round 3 prioritization may have been more useful if people were required to vote "most important" on the top 15 selections to help narrow down the pool.
12	5	6	4	4	6	1	(1) Collapse all of the decaBDE info into an executive summary and separate from the MWCNT info. (2) Improve the analysis and presentation of Round 1 results. (3) Eliminate Round 3.

Participant ID	Question 7 (#)	Question 7 (Text)	Question 7b	Question 8 (#)	Question 8 (Text)	Question 8b
1	4	Somewhat satisfied		4	Somewhat satisfied	
2	6	Very satisfied		5	Satisfied	
3	5	Satisfied		5	Satisfied	
4	6	Very satisfied		6	Very satisfied	
5	4	Somewhat satisfied	This process was improved from the nanosilver (I was dissatisfied there!) but still difficult to achieve sufficient detail.	5	Satisfied	
6	5	Satisfied		5	Satisfied	
7	5	Satisfied		6	Very satisfied	
8	4	Somewhat satisfied		4	Somewhat satisfied	
9	4	Somewhat satisfied	I didn't feel these would turn into "real" RRFs and if so I would have been more critical.	5	Satisfied	
10	5	Satisfied	I would have preferred more time to review the case study again in addition to the NGT.	5	Satisfied	
11	4	Somewhat satisfied	Some of the issues raised in the NGT would be important to include in management of MWCNT that did not make the final cut.	5	Satisfied	
12	5	Satisfied	The work group I was in was excellent and made it fun.	4	Somewhat satisfied	I have a sense that the workshop was more about beta testing CEA than setting a research agenda. Where is the budget to fund the work identified in the priorities?

Participant ID	Question 9	Question 10a	Question 10b
1		y	I was treated respectfully, I was allowed to express my ideas, and I learned a lot!
2	(1) NGT ranking was very useful; however redoing the prioritization tool #3 was not so much. Perhaps in third time the panelists should be forced to tank top 10 (?). This would strongly demonstrate the common areas of most concern. (2) Under the Elements it might be useful to combine some of the RRFs (ex: Recycling Volume & Release).	y	Great way to discuss a variety of views with experts
3		y	Good overview.
4	Adding a section during Rounds 1 & 2, before NGT discussion, for module modification.	y	Informative session.
5	Work products ok; difficult process in general; so I think it went well.	y	The CEA process is very interesting and it was a good experience; much better than nanosilver.
6		y	Should be useful for both business development and risk assessment.
7	One more synthesis step that would consider combining various E-RRF pairs to evolve research questions.	y	
8	I felt there was a disconnect between NGT consensus and prioritization results. I also wondered if anything was going to come out of our workshop.	y	Good opportunity to meet others in different disciplines. Also helped prioritize research.
9		y	
10	I think the facilitators did a great job of conveying the limits of the CEA process despite the participants resisting as much. I would also have preferred more time to review my charge question responses.	y	
11	Options for field experts to provide recommendations on what areas and factors should also be included in the risk management/assessment after Round 1 prioritization could have helped make the spreadsheet more encompassing.	y	Very well organized and efficient.
12	(1) More sophisticated presentation of results from Round 1 & 2 included presentation of ranges of responses and focus on the extremes as much as on the central tendencies. (2) Use a better ranking method—adding percentages of importance and no confidence is very shady. Because importance had three choices and NC had two choices they are unequal to start.	y	Interactions with talented folks from different fields is invaluable.

Table B-7. Summary statistics for participant responses from CEA MWCNT Prioritization Workshop Evaluation Form[2]

Question (abbreviated)	Median	Mean	Standard Deviation	Mode	Sum
2a. What was your experience regarding access to information about the expectations and methods for the online, pre-workshop portions of the CEA MWCNT Prioritization Process?	5.00	5.17	0.83	5	62
3a. What was your experience regarding the understandability of the CEA MWCNT Prioritization Process itself?	5.00	4.42	1.00	5	53
4a. What was your experience regarding access to information about the expectations and methods for carrying out the in-person workshop portions of the CEA MWCNT Prioritization Process?	6.00	5.50	0.67	6	66
5(1). Please rate the step “Reading Case Study” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	6	5.58	0.51	6	67
5(2). Please rate the step “Round 1 Prioritization” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	5	4.75	1.22	5	57
5(3). Please rate the step “Reviewing Round 1 Results Independently” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	4.5	4.58	0.90	4	55
5(4). Please rate the step “Round 2 Prioritization” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	4.5	4.42	1.08	5	53
5(5). Please rate the step “NGT Discussion of Priority E-RRFs” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	6	5.50	0.67	6	66
5(6). Please rate the step “Round 3 Prioritization” of the CEA Prioritization Process as to how useful it was in shaping your ultimate views of the most important priority areas on which to focus future research.	4	4.00	1.60	4	48
7a. How satisfied are you that the outputs of this workshop included detailed, actionable research questions that, if pursued, would enable assessment and subsequent management of MWCNT risks?	5.00	4.75	0.75	4	57
8a. How satisfied are you that the outputs of this workshop linked the recommended research to the risk assessment and risk management actions the research would support?	5.00	4.92	0.67	5	59

[2] The numeric responses are based on a Likert scale from 1 to 6, where 1 is Very Unsatisfied and 6 is Very Satisfied, or for the sub-questions for Question 5, 1 is Not Useful and 6 is Very Useful.

B.6 Overview of Participant Feedback Based on Evaluation Form

Out of 13 participants at the workshop, 12 completed the evaluation form. Overall, participant feedback about the CEA MWCNT Prioritization Process was generally positive. This is exemplified by the fact that all twelve respondents answered "Yes" to Question 10a, "Would you recommend this workshop to others?" Among other findings, some of the most common positive feedback responses included the following:

- The NGT process was productive and enjoyable.
- The workshop facilitation was effective.
- The workshop was an effective way to interact with diverse experts in a professional, respectful setting.

Some of the most common criticisms from responses included:

- The CEA MWCNT Prioritization Tool was difficult to use and took too long to fill out.
- Rounds of Prioritization 2 and 3 were not as helpful as Round 1, and could potentially be scaled down or skipped altogether.
- Additional "Other" categories of responses/options/influential factors and integrating all "Other" categories more fully into results reports would have been helpful.
- Additional time to review the MWCNT Draft Case Study Document prior to/during the workshop would have been helpful.

In terms of the effectiveness and clarity of communication, participants were generally satisfied with the access to information and understandability of the prioritization process, both the online and in-person portions of the process. In terms of the utility of the prioritization process, reading the case study and the NGT process were found to be most useful to participants while reviewing Round 1 and Round 2 prioritization were least useful. There were numerous suggestions to improve the process, including more NGT, less prioritization rounds, and the removal of the Influential Factors list (see **Table A-1** in **Appendix A**). Finally, for the workshop outputs, the participants were generally satisfied with the outputs of the workshop and the link between research and risk assessment and risk management actions.

Appendix C
Methods for Analysis and Reporting

Appendix C
Methods for Analysis and Reporting

C.1 Methodology for Analyzing and Reporting Round 1 Results

Several reports were prepared based on the results of Comprehensive Environmental Assessment (CEA) Prioritization Round 1. These reports and their formats are explained in further detail in **Section 3**. These reports were shared with participants in preparation for CEA Prioritization Round 2 to expose participants to the ideas of others. The reports were generated by importing the participants' responses from the submitted copies of the CEA MWCNT Prioritization Tool (see **Appendix K**) into a Microsoft Access database, which was queried to supply data for Microsoft Excel spreadsheets that served as templates for the reports.

Specifically, the following reports were generated for participants to review (see **Sections 3.2** and **3.3** for additional details and **Appendix D** for all results from Round 1):

- CEA Importance/Confidence Matrix
- Group Bar Charts, including Group-Wide Element Importance Stacked Bar Charts and Group-Wide CEA Level-Specific Bar Charts
- Expertise-Specific, CEA-Level-Specific Bar Charts and Sector-Specific, CEA-Specific Bar Charts
- Group-Wide Exhaustive Tables (with and without Influential Factors)
- Participant-Specific Tables

Participants also received instructions for reviewing and interpreting the reports (see **Appendix K** for further details). These instructions provided step-by-step guidance, including the order in which to view the reports, the purpose of each report, and how to analyze the data by moving from reports of group-wide results to reports of fine-scale results in order to efficiently locate and consider the opinions of other participants. Mock versions of each report were included in the instructions for interpreting the reports.

C.2 Methodology for Analyzing and Reporting Round 2 Results

The same reports generated for Round 1 were also generated for Round 2. In addition to generating reports for participants, the CEA Importance/Confidence Matrix of Element-Risk Relevance Factor pairs (E-RRFs) was analyzed to select the E-RRF pairs that the participant group rated as being most important. For each E-RRF pair placed in the "Important" and "Not Confident" bin of the CEA Importance/Confidence Matrix by at least some participants, a score was calculated by adding the percentage of participants that rated its Importance as "Important" to the percentage of participants that rated its Confidence as "Not Confident" (described in further detail in **Section C.4**). For example, the Material Synthesis-Release Rate E-RRF pair was rated as “Important” by 61% of participants and as “Not Confident” by 36% of participants, so that each E-RRF pair’s score is 97 (61 + 36). Round 2 results were then also used to determine the distribution of expertise and sector areas in which to base the invitation to participants to attend the workshop, as described in **Section 2.5** above as well as in **Section B.2** of **Appendix B**.

C.3 Methodology for Analyzing and Reporting Round 3 Results

Round 3 results were analyzed the same way as results for Rounds 1 and 2. In addition to these results (see **Appendix F**), the 15 most commonly agreed upon prioritized E-RFF pairs generated from the results of Round 3 (see **Section C.4** for more detail) were addressed in detail by breakout groups, with the purposes of generating actionable research questions and illuminating the connection between the necessary research, the assessments this research would support (e.g., human health risk assessment, ecological risk assessment, life cycle assessment), and ultimately, the risk-management decisions those assessments would inform. See **Section 2.5.2** for more information regarding the breakout groups and **Section C.4** for information on how these 15 prioritized E-RRFs were identified.

C.4 Determining Which CEA Research Areas Were Addressed in Breakout Groups

Although the method of identifying which of the participants in the larger group would attend the workshop considered all red and orange E-RRFs after Round 2 as a group of prioritized areas (see **Section B.2** in **Appendix B**), for the purposes of determining which E-RRFs would be addressed in detail during the workshop by breakout groups, it was necessary to define a way to rank the individual E-RRF pairs against one another. Within each box of the matrix obtained after Round 2, the aggregated data were presented in terms of E-RRF pair name: percentage of participants who chose that box’s importance rating (representing the most frequently selected rating for that E-RRF) and percentage of participants who chose that confidence rating (again representing the most frequently selected rating for that E-RRF). (See **Tables 3, 5,** and **7** in **Section 3** for these data from all three prioritization rounds).

To rank the E-RRF pairs in order of most commonly agreed upon for prioritization to least commonly agreed upon for prioritization by participants, boxes of the same color were considered together. Within one color group of the boxes, the percentage of participants who selected that Importance rating was added to the percentage of participants who selected that Confidence rating in Round 3 of prioritization (termed the “additive method”):

$$S_{E-RRF} = IE - RRF \quad + C_{E-RRF}$$

Where

S_{E-RRF}	=	overall score
I_{E-RRF}	=	percentage of all participants who chose that bin’s Importance rating
C_{E-RRF}	=	percentage of all participants who chose that bin’s Confidence rating.

These variables refer to the same E-RRF pair.

The E-RRF pairs were then ranked in descending order of their combined scores, and the top 15 scoring E-RRF pairs were addressed in more detail by the breakout groups. The cut-off number of 15 E-RRF pairs was chosen based on the decision to limit the number of people per breakout group so that each participant would have the chance to offer his/her insight, as well as the decision to assign no more than two or three E-RRF pairs to a group. Because there were a total of 13 participants at the workshop, four breakout groups were formed (i.e., three groups with three participants and one group with four participants; see **Table J-4** in **Appendix J**).

In addition to the additive method described previously, alternative methods to rank the E-RRF pairs were also explored, including choosing the E-RRF pairs that were farthest from the origin (0, 0) on a Confidence/Importance scatter plot. For exploring this alternative method (i.e., distance from origin), the resulting top 15 rankings of E-RRF pairs from Round 2 were essentially identical to those resulting from the additive method described previously. The additive method to rank the E-RRF pairs was therefore chosen for reasons of transparency, in that the additive method is simple, easily understood, and does not attempt to provide a level of mathematical sophistication that may not be well-suited for this prioritization process. Moreover, simpler mathematical methods are often preferred over potentially overly-complex methods, especially in cases of uncertainty, in order to better elicit relationships between two variables[1], in our case "Importance" and "Confidence."

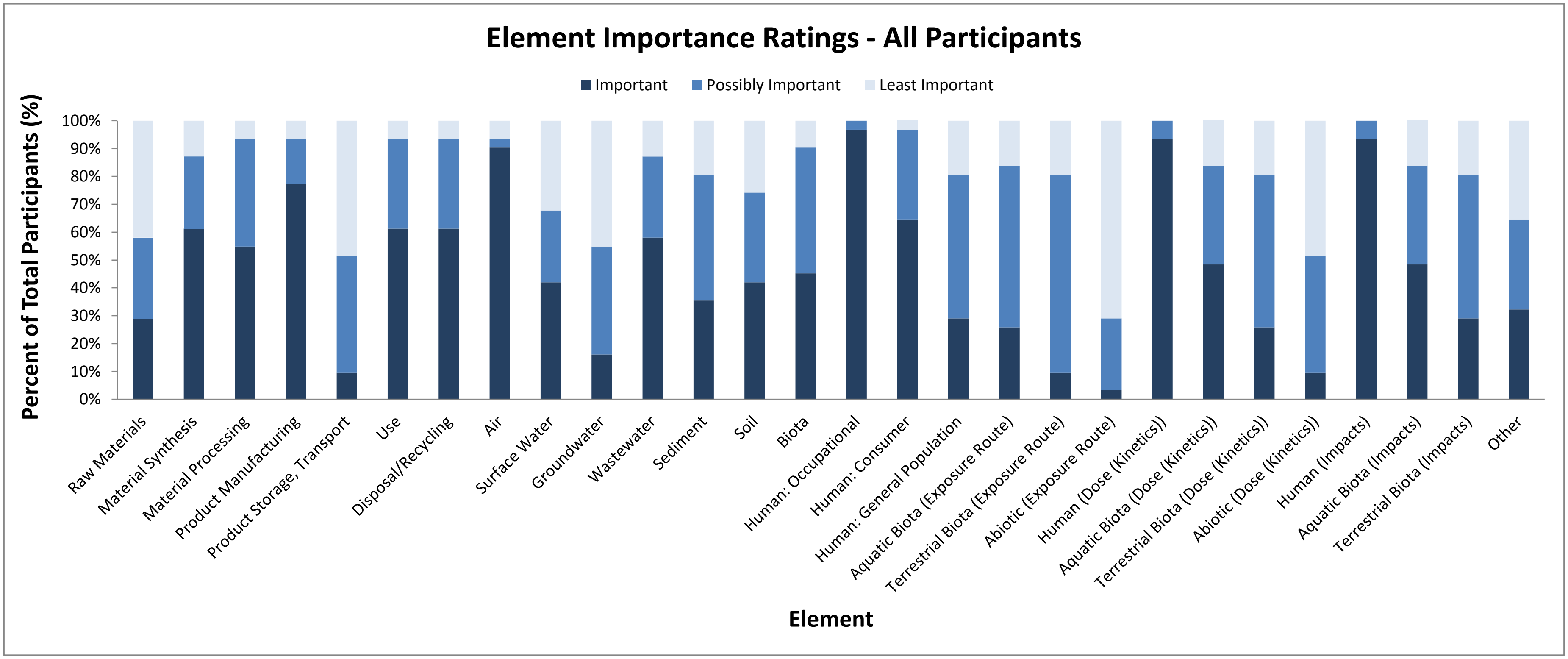
[1] E.g., Efron et al., 2004 (see http://arxiv.org/pdf/math/0406456.pdf).

Appendix D
Results from Round 1

Appendix D: Results from Round 1

Contents:

1. Group Results: Element Importance Stacked Bar Chart



Element Importance Ratings - All Participants
Important
Possibly Important
Least Important
Percent of Total Participants (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Raw Materials
Material Synthesis
Material Processing
Product Manufacturing
Product Storage, Transport
Use
Disposal/Recycling
Air
Surface Water
Groundwater
Wastewater
Sediment
Soil
Biota
Human: Occupational
Human: Consumer
Human: General Population
Aquatic Biota (Exposure Route)
Terrestrial Biota (Exposure Route)
Abiotic (Exposure Route)
Human (Dose (Kinetics))
Aquatic Biota (Dose (Kinetics))
Terrestrial Biota (Dose (Kinetics))
Abiotic (Dose (Kinetics))
Human (Impacts)
Aquatic Biota (Impacts)
Terrestrial Biota (Impacts)
Other
Element

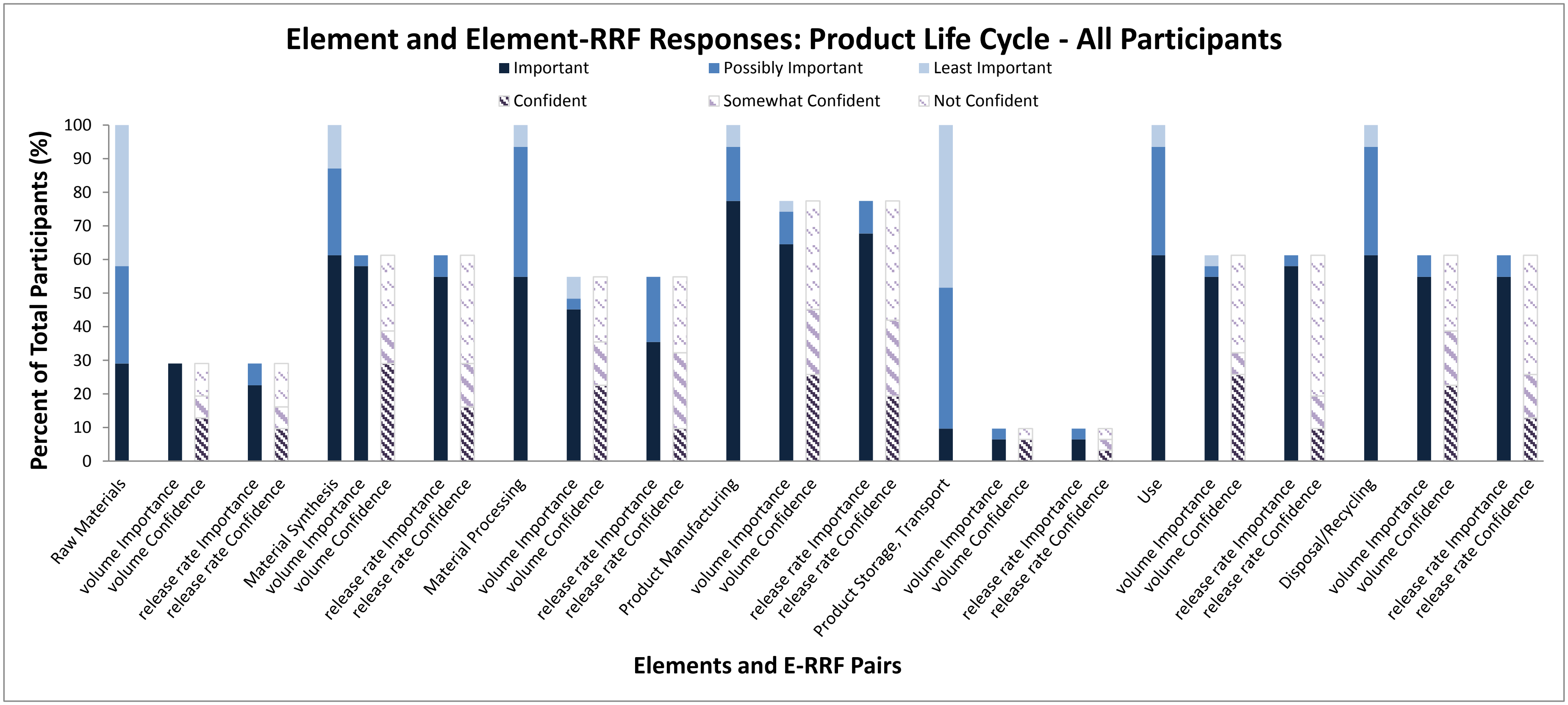
2. Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (E-RRF) Pairs

Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (RRF) Pairs - All Participants

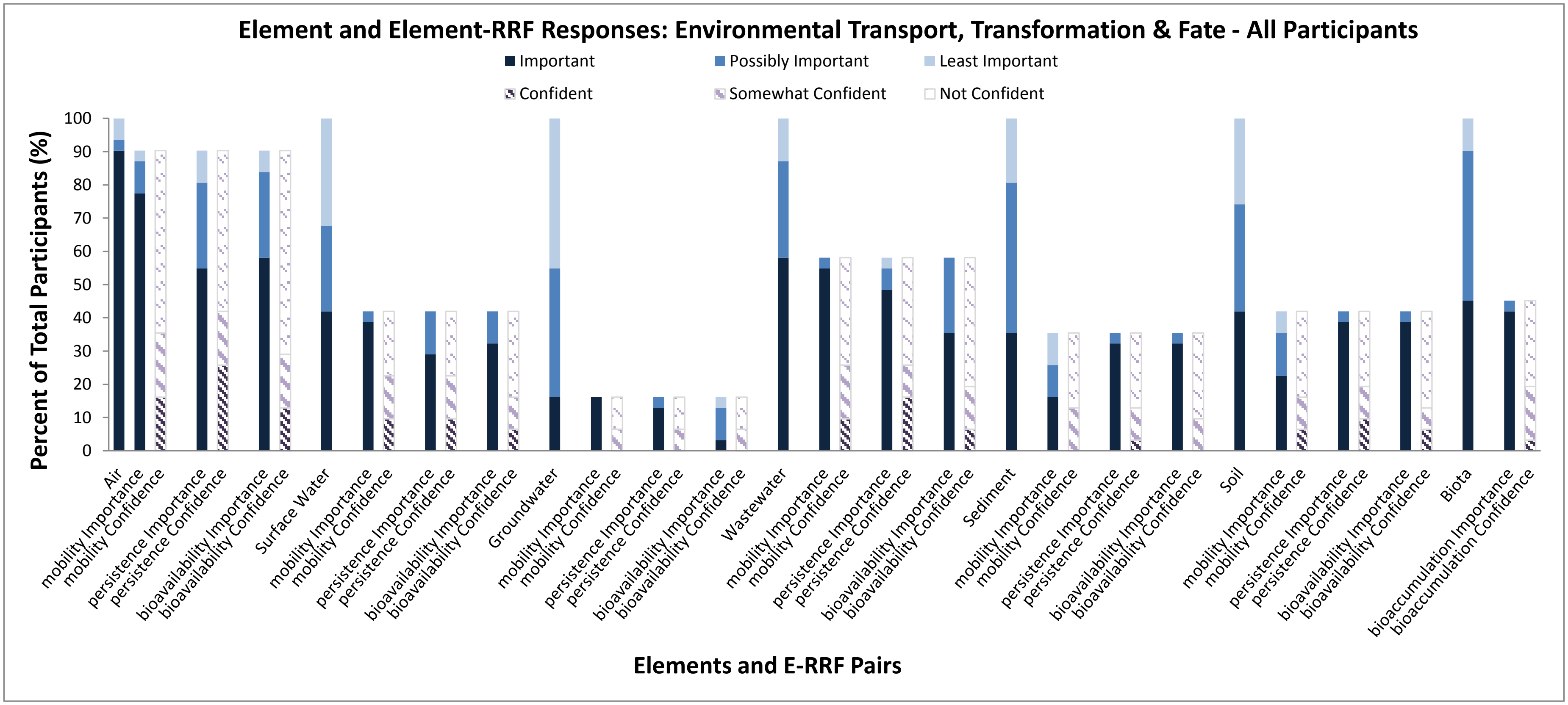
*I: %; C: % represents the percentage of total respondents who chose the cell's Importance and Confidence responses, respectively, for the listed Element-Risk Relevance Factor.

	Confident	Somewhat Confident	Not Confident
Important	• Product Life Cycle-Material Synthesis-Volume, I: 58%; C: 29% • Product Life Cycle-Material Processing-Volume, I: 45%; C: 23% • Product Life Cycle-Disposal/Recycling-Volume, I: 55%; C: 23%	• Product Life Cycle-Material Processing-Release Rate, I: 35%; C: 23% • Exposure Route-Human: Occupational-Inhalation, I: 97%; C: 39% • Impacts-Aquatic Biota-Survival, I: 35%; C: 19%	• Product Life Cyc e Mater a Synthes s Re ease Rate, I: 55%; C: 32% • Product L fe Cycle Product Manufactur ng Vo ume, I: 65%; C: 32% • Product L fe Cycle Product Manufactur ng Re ease Rate, I: 68%; C: 35% • Product Life Cycle Use Volume, I: 55%; C: 29% • Product Life Cycle Use Release Rate, I: 58%; C: 42% • Product L fe Cycle D sposa /Recycl ng Re ease Rate, I: 55%; C: 35% • Env. TT&F Air Mobility, I: 77%; C: 55% • Env. TT&F Air Persistence, I: 55%; C: 48% • Env. TT&F Air Bioavailability, I: 58%; C: 61% • Env. TT&F Surface Water Mobility, I: 39%; C: 19% • Env. TT&F Surface Water Persistence, I: 29%; C: 19% • Env. TT&F Surface Water Bioavailability, I: 32%; C: 26% • Env. TT&F Wastewater Mobility, I: 55%; C: 32% • Env. TT&F Wastewater Persistence, I: 48%; C: 32% • Env. TT&F Wastewater Bioavailability, I: 35%; C: 39% • Env. TT&F Soil Mobility, I: 23%; C: 26% • Env. TT&F Soil Persistence, I: 39%; C: 23% • Env. TT&F Soil Bioavailability, I: 39%; C: 29% • Env. TT&F Biota Bioaccumulation, I: 42%; C: 26% • Exposure Route Human: Consumer Ingest on, I: 35%; C: 39% • Exposure Route Human: Consumer Inha at on, I: 52%; C: 35% • Dose (Kinetics)-Human Absorption, I: 77%; C: 61% • Dose (Kinetics)-Human Distribution, I: 71%; C: 61% • Dose (Kinetics)-Human Metabolism, I: 48%; C: 68% • Dose (Kinetics)-Human Excretion, I: 65%; C: 65% • Dose (Kinetics)-Aquatic Biota Absorption, I: 39%; C: 23% • Dose (Kinetics)-Aquatic Biota Distribution, I: 39%; C: 32% • Dose (Kinetics)-Aquatic Biota Metabolism, I: 23%; C: 35% • Dose (Kinetics)-Aquatic Biota Excretion, I: 32%; C: 32% • Impacts Human Cancer, I: 74%; C: 52% • Impacts Human Non cancer, I: 68%; C: 45% • Impacts Aquatic Biota Developmental, I: 29%; C: 32% • Impacts Aquat c B ota Reproduct ve, I: 29%; C: 32% • Impacts Aquat c B ota Other Sub etha Endpo nts, I: 16%; C: 32%
Possibly Important			• Exposure Route-Human: Occupational-Ingestion, I: 45%; C: 45% • Exposure Route-Human: Occupational-Dermal, I: 39%; C: 45% • Exposure Route-Human: Consumer-Dermal, I: 26%; C: 39% • Impacts-Human-Reproductive/ Developmental, I: 48%; C: 68%
Least Important			

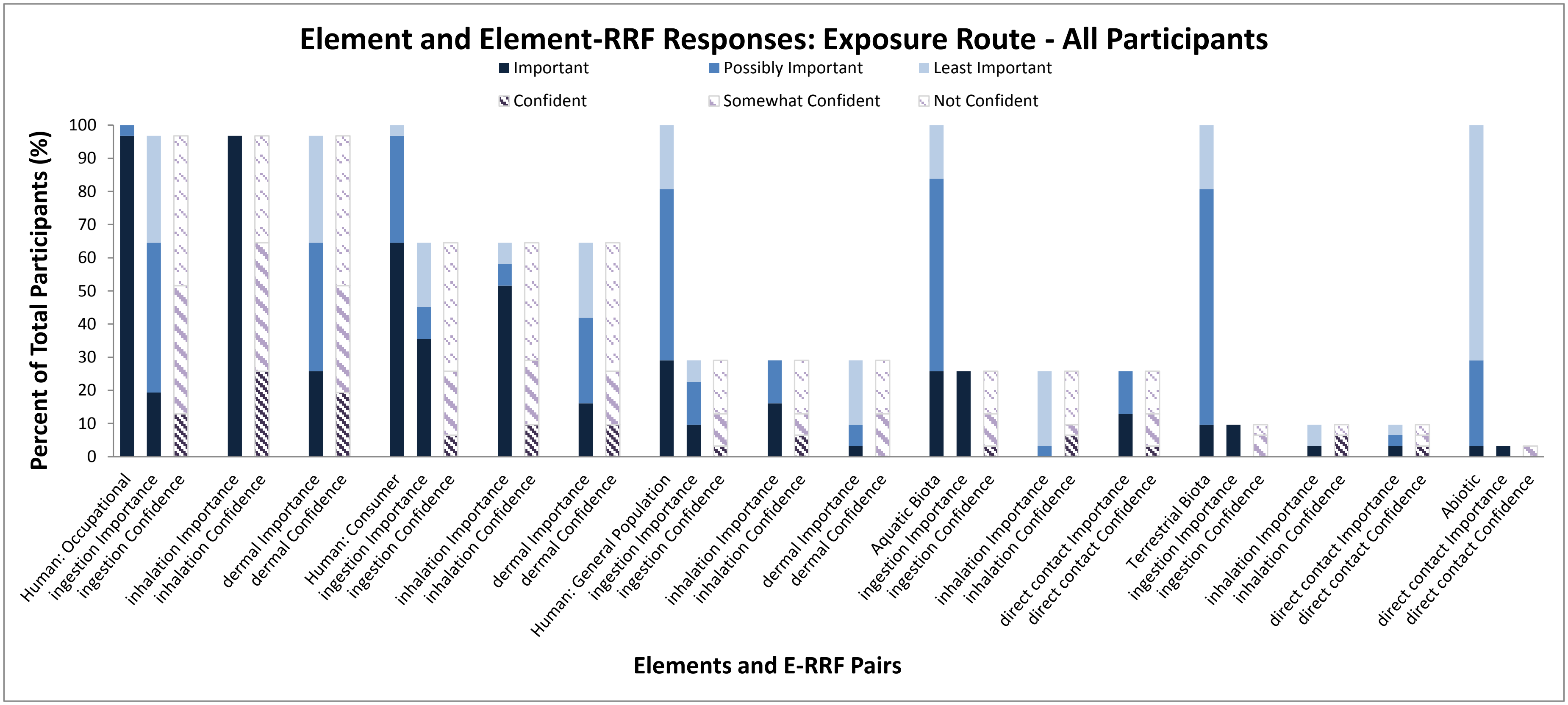
3. Group-Wide CEA Level-Specific Bar Charts



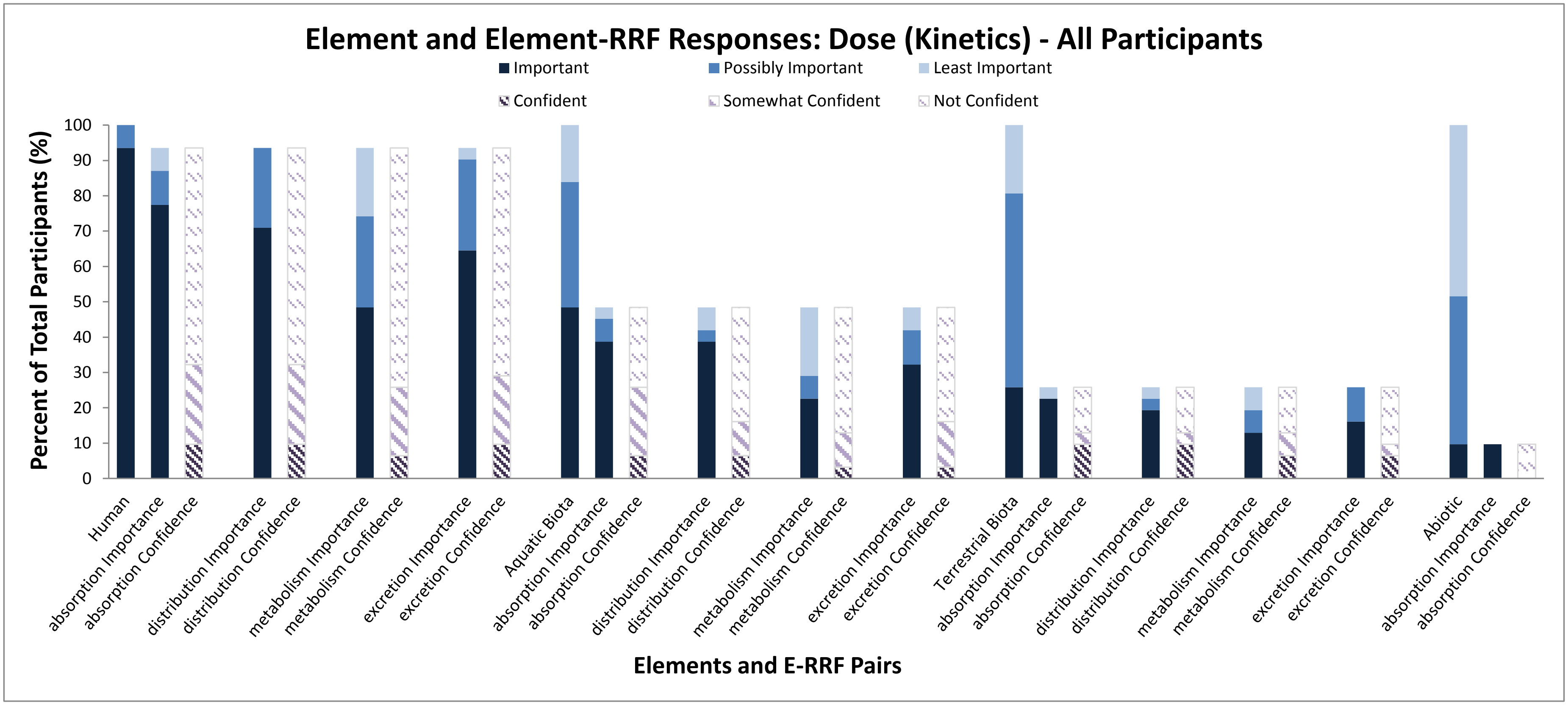
Element and Element-RRF Responses: Product Life Cycle - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Raw Materials
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Synthesis
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Processing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Manufacturing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Storage, Transport
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Use
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Disposal/Recycling
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Elements and E-RRF Pairs



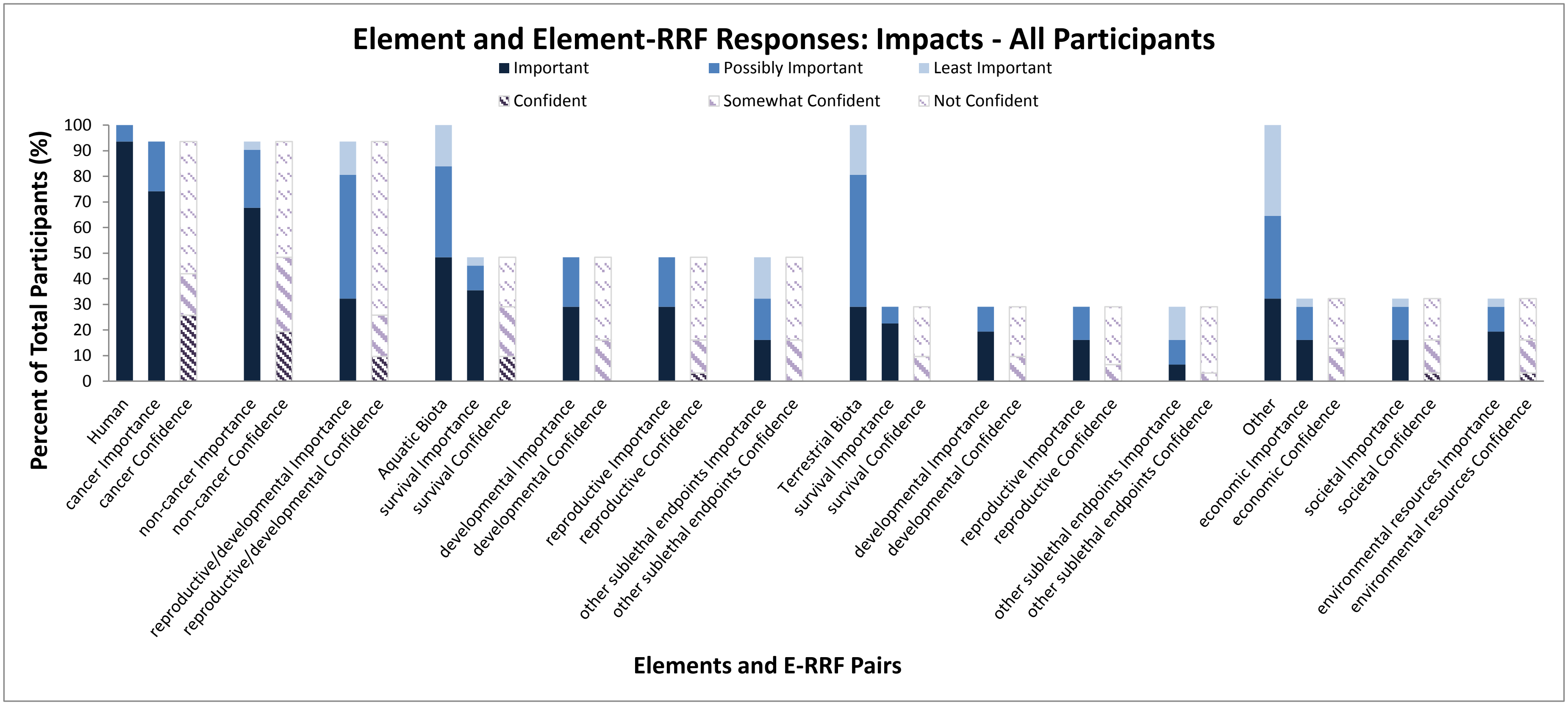
Element and Element-RRF Responses: Environmental Transport, Transformation & Fate - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Air
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Surface Water
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Groundwater
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Wastewater
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Sediment
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Soil
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Biota
bioaccumulation Importance
bioaccumulation Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Exposure Route - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Human: Occupational
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: Consumer
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: General Population
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Aquatic Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Terrestrial Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Abiotic
direct contact Importance
direct contact Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Dose (Kinetics) - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Human
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Aquatic Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Terrestrial Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Abiotic
absorption Importance
absorption Confidence
Elements and E-RRF Pairs


Element and Element-RRF Responses: Impacts - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Human
cancer Importance
cancer Confidence
non-cancer Importance
non-cancer Confidence
reproductive/developmental Importance
reproductive/developmental Confidence
Aquatic Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Terrestrial Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Other
economic Importance
economic Confidence
societal Importance
societal Confidence
environmental resources Importance
environmental resources Confidence
Elements and E-RRF Pairs

4. Group Results: Table (with Influential Factors)

Please refer to **Figure 8** in the Summary Report for an overview and explanation of the color-coding of the rows in this table. For example, red rows indicate that the row's Element-Risk Relevance Factor (E-RRF) pair is grouped in the "Important" and "Not Confident" bin of the Importance/Confidence Matrix of E-RRF pairs.

* Represents the number and percentage of participants who ranked the row's Element-Risk Relevance Factor (E-RRF) Pair with the corresponding column's selection.

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
1	Raw Materials-Volume	9(#); 29(%)*	9(#); 29(%)	13(#); 42(%)	9(#); 29(%)	0(#); 0(%)	0(#); 0(%)	4(#); 13(%)	2(#); 6(%)	3(#); 10(%)	• essential for exposure analysis • need to be able to identify impurities including amounts • proportional to exposure • "reported" data from major industries are more likely to represent a proximal value close to real one(s) • absence of manufacturing data • MWCNT volumes will be application driven, and field is still too new to really say what projected volumes will really be	• Analytical Techniques 1(#); 3(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 3(#); 10(%) • MWCNT Purity 3(#); 10(%) • MWCNT Synthesis Methods 3(#); 10(%) • Personal Protective Equipment 2(#); 6(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 3(#); 10(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 4(#); 13(%) • Charge 4(#); 13(%) • Conductive or Magnetic Properties 3(#); 10(%) • Crystalline Phase 3(#); 10(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 3(#); 10(%) • Redox Potential 4(#); 13(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 3(#); 10(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 2(#); 6(%) • Sediment 2(#); 6(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 2(#); 6(%) • Wind 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 2(#); 6(%) • pH 2(#); 6(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 2(#); 6(%) • Human Activity 2(#); 6(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 2(#); 6(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
2	Raw Materials-Release Rate	9(#); 29(%)	9(#); 29(%)	13(#); 42(%)	7(#); 23(%)	2(#); 6(%)	0(#); 0(%)	3(#); 10(%)	2(#); 6(%)	4(#); 13(%)	• essential for exposure analysis • proportional to exposure • lack of adequate published data on MWCNT and byproducts • release rate will be governed by a lot of engineering and manufacturing issues, also not known yet, especially since actual application is still unknown • lack of release data • the pool size of the data available is too small to maintain the validity of any claim	• Analytical Techniques 2(#); 6(%) • Control Technologies 3(#); 10(%) • MWCNT Processing Methods 3(#); 10(%) • MWCNT Purity 4(#); 13(%) • MWCNT Synthesis Methods 5(#); 16(%) • Personal Protective Equipment 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 4(#); 13(%) • Applied Coatings 3(#); 10(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 4(#); 13(%) • Charge 4(#); 13(%) • Conductive or Magnetic Properties 3(#); 10(%) • Crystalline Phase 3(#); 10(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 4(#); 13(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 4(#); 13(%) • Structural Formula/Molecular Structure 4(#); 13(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 3(#); 10(%) • Groundwater 3(#); 10(%) • Sediment 3(#); 10(%) • Soil 3(#); 10(%) • Surface Water 3(#); 10(%) • Wastewater 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 0(#); 0(%) • Soil Porosity 3(#); 10(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 3(#); 10(%) • Wind 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 3(#); 10(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 3(#); 10(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 3(#); 10(%) • Exposure Route 3(#); 10(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 3(#); 10(%) • Human Activity 3(#); 10(%) • Individual Activity Level 3(#); 10(%) • Life Stage 3(#); 10(%) • Occupation 3(#); 10(%) • Subchronic Exposure 3(#); 10(%) • Susceptible Populations/Individuals 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
3	Material Synthesis-Volume	19(#); 61(%)	8(#); 26(%)	4(#); 13(%)	18(#); 58(%)	1(#); 3(%)	0(#); 0(%)	9(#); 29(%)	3(#); 10(%)	7(#); 23(%)	• data from small scale R&D facilities only • essential for exposure analysis • proportional to exposure • first principles • majority of "synthesized" CNTs produced are believed to come from commercial sectors that do not have specific reasons to manipulate the amount of CNTs they produce • lack of adequate published data on MWCNT and byproducts • true volumes not known • the volume of production influences the potential for exposure and therefore is important information to have. Volume production information is in existance but due to the lack of reporting schemes, may be an underestimation • manufacturers rarely reveal this information yet this information informs modeling about potential concentrations in the environment • proportion of MWCNT made during synthesis is unclear. Contamination level can vary between samples • since applications for MWCNT are not well defined, how they will be used in material synthesis is unclear	• Analytical Techniques 4(#); 13(%) • Control Technologies 6(#); 19(%) • MWCNT Processing Methods 8(#); 26(%) • MWCNT Purity 7(#); 23(%) • MWCNT Synthesis Methods 9(#); 29(%) • Personal Protective Equipment 6(#); 19(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 6(#); 19(%) • Applied Coatings 5(#); 16(%) • Biodegradability 2(#); 6(%) • Catalytic Activity 4(#); 13(%) • Charge 6(#); 19(%) • Conductive or Magnetic Properties 3(#); 10(%) • Crystalline Phase 3(#); 10(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 7(#); 23(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 19(%) • Persistence 3(#); 10(%) • Redox Potential 5(#); 16(%) • Size/Size Distribution 7(#); 23(%) • Specific Surface Area 6(#); 19(%) • Structural Formula/Molecular Structure 5(#); 16(%) • Surface Chemistry 6(#); 19(%) • Water Solubility/Dispersibility 7(#); 23(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 6(#); 19(%) • Groundwater 3(#); 10(%) • Sediment 3(#); 10(%) • Soil 4(#); 13(%) • Surface Water 2(#); 6(%) • Wastewater 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 2(#); 6(%) • Wind 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 3(#); 10(%) • Dispersing Agents 6(#); 19(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 3(#); 10(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 3(#); 10(%) • Other Contaminants in Environment 3(#); 10(%) • pH 2(#); 6(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 10(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 3(#); 10(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 6(#); 19(%) • Chronic Exposure 6(#); 19(%) • Exposure Route 6(#); 19(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 2(#); 6(%) • Human Activity 5(#); 16(%) • Individual Activity Level 6(#); 19(%) • Life Stage 2(#); 6(%) • Occupation 5(#); 16(%) • Subchronic Exposure 4(#); 13(%) • Susceptible Populations/Individuals 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
4	Mater a Synthes s Release Rate	19(#) 61(%)	8(#) 26(%)	4(#) 13(%)	17(#) 55(%)	2(#) 6(%)	0(#) 0(%)	5(#) 16(%)	4(#) 13(%)	10(#) 32(%)	• essentia for exposure ana ys s • proportiona to exposure • f rst pr nc p es • there are mu tip e var ab es nvo ved n th s "release" mechan sm that we do not have enough data • data from sma sca e R&D fac ties on y • ack of adequate pub shed data on MWCNT and byproducts • potentia for release unknown • release rate (and partic e character stics) s very mportant n estimating potentia for exposure of production workers yet a most no nformation exists espec a y n mass production fac ties greatest cha enges are n mon tor ng techn ques • s nce app cations for MWCNT are not wel defined how they wou d be released from mater a synthetetic operations (putt ng the MWCNT nto a product) cannot be determined • release evels can be approximated fa r y wel • ack of release data nc ud ng mpur ties • tt e nformation s ava ab e about th s step for d fferent synthes s approaches	• Ana ytica Techn ques 9(#) 29(%) • Contro Techno og es 10(#) 32(%) • MWCNT Process ng Methods 9(#) 29(%) • MWCNT Pur ty 8(#) 26(%) • MWCNT Synthes s Methods 11(#) 35(%) • Persona Protective Equ pment 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 19(%) • Aggregation/Agg omeration State 10(#) 32(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 6(#) 19(%) • Charge 7(#) 23(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 10(#) 32(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 29(%) • Pers stence 7(#) 23(%) • Redox Potentia 6(#) 19(%) • S ze/S ze D str bution 10(#) 32(%) • Spec f c Surface Area 9(#) 29(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 4(#) 13(%) • Sed ment 5(#) 16(%) • So 6(#) 19(%) • Surface Water 3(#) 10(%) • Wastewater 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 4(#) 13(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 3(#) 10(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 7(#) 23(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 3(#) 10(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 1(#) 3(%) • Natura Organ c Matter (NOM) 4(#) 13(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 3(#) 10(%) • Surfactant (in Lab) 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 10(%) • B oaccumu ation 5(#) 16(%) • B omagn f cation 4(#) 13(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 2(#) 6(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 23(%) • Chron c Exposure 8(#) 26(%) • Exposure Route 7(#) 23(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 3(#) 10(%) • Occupation 7(#) 23(%) • Subchron c Exposure 6(#) 19(%) • Susceptib e Popu ations/ nd v dua s 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
5	Material Processing-Volume	17(#); 55(%)	12(#); 39(%)	2(#); 6(%)	14(#); 45(%)	1(#); 3(%)	2(#); 6(%)	7(#); 23(%)	4(#); 13(%)	6(#); 19(%)	• need to estimate exposures • proportional to exposure • no good studies • if the volumes of strong acids, etc. that may be required for MWNT processing (purification, functionalization) are significant then it may pose a risk to the environment in terms of energy used and waste generated. Specific processes that will be required • lack of adequate published data on MWCNT and byproducts • very little data available; processes are not mature • application and actual use not well defined, so the process volumes and release rates will also be unknown • volume of material process heavily influences the potential for exposure and therefore is important information to have particulary as this is step in life cycle has a large potential for material release and exposure • first principles • important to know how many workers might be potentially exposed • no motivation for commercial sectors to falsely report on the volvume of CNTs that they produce at this point	• Analytical Techniques 4(#); 13(%) • Control Technologies 7(#); 23(%) • MWCNT Processing Methods 6(#); 19(%) • MWCNT Purity 5(#); 16(%) • MWCNT Synthesis Methods 5(#); 16(%) • Personal Protective Equipment 4(#); 13(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 10(%) • Aggregation/Agglomeration State 5(#); 16(%) • Applied Coatings 5(#); 16(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 3(#); 10(%) • Charge 4(#); 13(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 3(#); 10(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 16(%) • Persistence 4(#); 13(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 5(#); 16(%) • Structural Formula/Molecular Structure 4(#); 13(%) • Surface Chemistry 5(#); 16(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 4(#); 13(%) • Groundwater 3(#); 10(%) • Sediment 2(#); 6(%) • Soil 3(#); 10(%) • Surface Water 4(#); 13(%) • Wastewater 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 1(#); 3(%) • Soil Porosity 3(#); 10(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 2(#); 6(%) • Wind 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 5(#); 16(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 5(#); 16(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 3(#); 10(%) • Other Contaminants in Environment 5(#); 16(%) • pH 4(#); 13(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 3(#); 10(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 10(%) • Chronic Exposure 4(#); 13(%) • Exposure Route 3(#); 10(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 2(#); 6(%) • Human Activity 3(#); 10(%) • Individual Activity Level 3(#); 10(%) • Life Stage 3(#); 10(%) • Occupation 3(#); 10(%) • Subchronic Exposure 3(#); 10(%) • Susceptible Populations/Individuals 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
6	Material Processing-Release Rate	17(#); 55(%)	12(#); 39(%)	2(#); 6(%)	11(#); 35(%)	6(#); 19(%)	0(#); 0(%)	3(#); 10(%)	7(#); 23(%)	7(#); 23(%)	• proportional to exposure • lack of adequate published data on MWCNT and byproducts • no good studies / limited amount of studies • lack of release data at premanufacturing facilities • release rate (and particle characteristics) is very important in estimating potential for exposure of production workers yet almost no information exists especially in mass production • processing facilities - greatest challenges are in monitoring techniques • application and actual use not well defined, so the process volumes and release rates will also be unknown • control of dust not known; exposures expected to be greatest at this stage • first principles • methods and mechanisms exist for handling of standard chemicals such as oxidizing acids and release rates should be able to be minimized	• Analytical Techniques 7(#); 23(%) • Control Technologies 9(#); 29(%) • MWCNT Processing Methods 10(#); 32(%) • MWCNT Purity 5(#); 16(%) • MWCNT Synthesis Methods 4(#); 13(%) • Personal Protective Equipment 7(#); 23(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 19(%) • Aggregation/Agglomeration State 8(#); 26(%) • Applied Coatings 8(#); 26(%) • Biodegradability 5(#); 16(%) • Catalytic Activity 5(#); 16(%) • Charge 6(#); 19(%) • Conductive or Magnetic Properties 4(#); 13(%) • Crystalline Phase 3(#); 10(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 7(#); 23(%) • Morphology (e.g. aspect ratio, length, width, shape) 8(#); 26(%) • Persistence 7(#); 23(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 7(#); 23(%) • Specific Surface Area 7(#); 23(%) • Structural Formula/Molecular Structure 5(#); 16(%) • Surface Chemistry 8(#); 26(%) • Water Solubility/Dispersibility 8(#); 26(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 6(#); 19(%) • Groundwater 4(#); 13(%) • Sediment 4(#); 13(%) • Soil 4(#); 13(%) • Surface Water 6(#); 19(%) • Wastewater 6(#); 19(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 3(#); 10(%) • Light Availability 2(#); 6(%) • Soil Porosity 4(#); 13(%) • Soil/Sediment Fractionation 4(#); 13(%) • Temperature 3(#); 10(%) • Wind 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 3(#); 10(%) • Dispersing Agents 7(#); 23(%) • Dissolved Oxygen Content 2(#); 6(%) • Exposure to Sunlight 3(#); 10(%) • Heavy Metals in Environment 5(#); 16(%) • Ionic Strength in Environment 3(#); 10(%) • Ligand Concentrations in Environment 3(#); 10(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 5(#); 16(%) • pH 4(#); 13(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 2(#); 6(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 5(#); 16(%) • Biomagnification 3(#); 10(%) • Microbial Communities in Environment 2(#); 6(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 16(%) • Chronic Exposure 6(#); 19(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 3(#); 10(%) • Human Activity 5(#); 16(%) • Individual Activity Level 5(#); 16(%) • Life Stage 4(#); 13(%) • Occupation 5(#); 16(%) • Subchronic Exposure 5(#); 16(%) • Susceptible Populations/Individuals 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
7	Product Manufactur ng Vo ume	24(#) 77(%)	5(#) 16(%)	2(#) 6(%)	20(#) 65(%)	3(#) 10(%)	1(#) 3(%)	8(#) 26(%)	6(#) 19(%)	10(#) 32(%)	• among the producers th s number shou d be obta nab e • proportiona to exposure • vo ume by any metr c s v ta n order to do any k nd of exposure assessment dur ng manufactur ng wh ch aga n s a fundamenta part of r sk assessment • ack of adequate pub shed data on MWCNT and byproducts • no good stud es • unsure about data qua ty • app cation and actua use not wel defined so the process vo umes and release rates w a so be unknown • release scenar os appear to be min ma stud es no mention of the contaminates (i.e. meta cata yst) • rel es upon manufacturer nformation • There s the potentia for mater a release dur ng manufacture and n partiu ar dur ng the celan ng processes and app cation of the f ame retardant to textiles The evel of release s kely to be reflected n the sca e of activ tis (as wel as n contro methods used) but there s tt e nformation on th s espec a y as the techno ogy for production s stil develop ng • f rst pr nc p es • ack of centra zed reporting system • measurement techn ques can estimate, but on y somewhat conf dent s nce % by weight of CNTs are ow n these mixtures tota vo ume of retardants wou d be necessary to understand potentia exposures t s not c ear what vo umes of products and correspond ng evel of r sks n manufactur ng w occur f t s a c osed shou dnt be a prob em	• Ana ytica Techn ques 7(#) 23(%) • Contro Techno og es 12(#) 39(%) • MWCNT Process ng Methods 12(#) 39(%) • MWCNT Pur ty 7(#) 23(%) • MWCNT Synthes s Methods 8(#) 26(%) • Persona Protective Equ pment 11(#) 35(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 26(%) • Aggregation/Agg omeration State 11(#) 35(%) • App ed Coatings 9(#) 29(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 6(#) 19(%) • Charge 9(#) 29(%) • Conductive or Magnetic Properties 5(#) 16(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 10(#) 32(%) • Pers stence 8(#) 26(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 10(#) 32(%) • Spec f c Surface Area 9(#) 29(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 10(#) 32(%) • Water So ub ty/D spers b ty 12(#) 39(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 29(%) • Groundwater 5(#) 16(%) • Sed ment 4(#) 13(%) • So 6(#) 19(%) • Surface Water 5(#) 16(%) • Wastewater 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 0(#) 0(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 2(#) 6(%) • W nd 4(#) 13(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 8(#) 26(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 3(#) 10(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 1(#) 3(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 3(#) 10(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 19(%) • B oaccumu ation 7(#) 23(%) • B omagn f cation 4(#) 13(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 8(#) 26(%) • Chron c Exposure 9(#) 29(%) • Exposure Route 7(#) 23(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 8(#) 26(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 3(#) 10(%) • Occupation 7(#) 23(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)
8	Product Manufactur ng Release Rate	24(#) 77(%)	5(#) 16(%)	2(#) 6(%)	21(#) 68(%)	3(#) 10(%)	0(#) 0(%)	6(#) 19(%)	7(#) 23(%)	11(#) 35(%)	• among the producers th s number shou d be obta nab e • one needs to know the release rate n order to assess the exposure potentia dur ng product manufactur ng • proportiona to exposure • ack of adequate pub shed data on MWCNT and byproducts • mited data • tt e nformation s ava ab e about how products wou d be manufacturer and how d fferent processes mpact release rates • no good stud es • app cation and actua use not wel defined so the process vo umes and release rates w a so be unknown • f rst pr nc p es • genera methods of app cation of MWCNT formu ations are known and can be used to nform potentia release rates • s nce the retardants are most kely to be app ed wet t wou d be necessary to know the potentia for release and exposure cou d p ay a ro e n ear y release, doesnt seem to matter n ater release stud es • am assuming th s refers to the CVD process and assoc ated hand ng	• Ana ytica Techn ques 12(#) 39(%) • Contro Techno og es 14(#) 45(%) • MWCNT Process ng Methods 13(#) 42(%) • MWCNT Pur ty 6(#) 19(%) • MWCNT Synthes s Methods 7(#) 23(%) • Persona Protective Equ pment 12(#) 39(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 26(%) • Aggregation/Agg omeration State 11(#) 35(%) • App ed Coatings 10(#) 32(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 5(#) 16(%) • Charge 9(#) 29(%) • Conductive or Magnetic Properties 5(#) 16(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 10(#) 32(%) • Pers stence 9(#) 29(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 11(#) 35(%) • Spec f c Surface Area 10(#) 32(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 10(#) 32(%) • Water So ub ty/D spers b ty 11(#) 35(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 10(#) 32(%) • Groundwater 5(#) 16(%) • Sed ment 5(#) 16(%) • So 7(#) 23(%) • Surface Water 7(#) 23(%) • Wastewater 10(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 4(#) 13(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 3(#) 10(%) • W nd 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 9(#) 29(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 5(#) 16(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 5(#) 16(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 4(#) 13(%) • Surfactant (in Lab) 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 19(%) • B oaccumu ation 8(#) 26(%) • B omagn f cation 5(#) 16(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 8(#) 26(%) • Chron c Exposure 9(#) 29(%) • Exposure Route 8(#) 26(%) • Geograph c Location (i.e. rura vs urban) 1(#) 3(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 4(#) 13(%) • Occupation 8(#) 26(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
9	Product Storage, Transport-Volume	3(#); 10(%)	13(#); 42(%)	15(#); 48(%)	2(#); 6(%)	1(#); 3(%)	0(#); 0(%)	2(#); 6(%)	0(#); 0(%)	1(#); 3(%)	• need to estimate exposures • proportional to exposures	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
10	Product Storage, Transport-Release Rate	3(#); 10(%)	13(#); 42(%)	15(#); 48(%)	2(#); 6(%)	1(#); 3(%)	0(#); 0(%)	1(#); 3(%)	1(#); 3(%)	1(#); 3(%)	• The question of what form of storage container is typically used by manufacturers of CNT exists. In personal experience small quatities (research batches) tend to be shipped in glass bottles or hard plastic containers whilst larger amounts (e.g. >1Kg) tend to be shipped in large heavy gauge plastic bags for which it is difficult to handle (i.e. they dont stand up) seal effectivly and keep clean. Therefore there is a great potential for release in normal handling • similar to other chemicals • proportional to exposure	• Analytical Techniques 1(#); 3(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 1(#); 3(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
11	Use-Vo ume	19(#) 61(%)	10(#) 32(%)	2(#) 6(%)	17(#) 55(%)	1(#) 3(%)	1(#) 3(%)	8(#) 26(%)	2(#) 6(%)	9(#) 29(%)	• among the producers th s number shou d be obta nab e • current f ame retardant coating exposure w th upho stery use s somewhat known R sk w th use of MWCNT product s not known • need to estimate exposures • the area treated w affect exposure. Need to estimate exposures • actua end use for MWCNT rea y not wel defined Cou d be we are ook ng at the r sk ssues n the comp etely wrong app cation • nformation s genera y not supp ed by the manufacturers about numbers of products and MWCNT concentrations n products • vo ume used s key n order to comp ete exposure assessments dur ng uses At the moment, we do either not have the nformation about uses and vo ume or we do not have access to such nformation	• Ana ytica Techn ques 4(#) 13(%) • Contro Techno og es 5(#) 16(%) • MWCNT Process ng Methods 4(#) 13(%) • MWCNT Pur ty 5(#) 16(%) • MWCNT Synthes s Methods 4(#) 13(%) • Persona Protective Equ pment 3(#) 10(%) • Other 4(#) 13(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 19(%) • Aggregation/Agg omeration State 7(#) 23(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 3(#) 10(%) • Charge 5(#) 16(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 2(#) 6(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 8(#) 26(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 6(#) 19(%) • Pers stence 7(#) 23(%) • Redox Potentia 3(#) 10(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 5(#) 16(%) • Surface Chem stry 6(#) 19(%) • Water So ub ty/D spers b ty 7(#) 23(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 2(#) 6(%) • Sed ment 3(#) 10(%) • So 5(#) 16(%) • Surface Water 2(#) 6(%) • Wastewater 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 0(#) 0(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 1(#) 3(%) • Temperature 2(#) 6(%) • W nd 1(#) 3(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 1(#) 3(%) • on c Strength n Env ronment 2(#) 6(%) • L gand Concentrations n Env ronment 0(#) 0(%) • Natura Organ c Matter (NOM) 2(#) 6(%) • Other Contaminants n Env ronment 1(#) 3(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 16(%) • B oaccumu ation 5(#) 16(%) • B omagn f cation 4(#) 13(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 2(#) 6(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 3(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 6(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 19(%) • Chron c Exposure 7(#) 23(%) • Exposure Route 7(#) 23(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 7(#) 23(%) • L fe Stage 4(#) 13(%) • Occupation 5(#) 16(%) • Subchron c Exposure 6(#) 19(%) • Susceptib e Popu ations/ nd v dua s 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
12	Use-Release Rate	19(#) 61(%)	10(#) 32(%)	2(#) 6(%)	18(#) 58(%)	1(#) 3(%)	0(#) 0(%)	3(#) 10(%)	3(#) 10(%)	13(#) 42(%)	• essentia for exposure ana ys s Proportiona to exposure • w depend on use pattern and fe • actua end use for MWCNT rea y not wel defined Cou d be we are ook ng at the r sk ssues n the comp etely wrong app cation • as n the case of product manufactur ng release rate s v ta n order to comp ete an exposure assessment dur ng uses • nformation on decaBDE release dur ng the use phase of a f ame retardent suggests that there s a cons derab e potentia for CNT release f used n a s mi ar manner (e.g textiles). the evel of release and phys cochem ca character stics of the released • ack of adequate pub shed data on var ous types of MWCNT • the rate of release of MWCNTs and assoc ated hazards from new to be made products s not wel known mostly because the exact mater a s formu ations processes products and use scenar os are to be determined • there are few stud es on release rates from products or po ymer nanocompos tes w th MWCNTs • s mi ar to other chem ca s	• Ana ytica Techn ques 12(#) 39(%) • Contro Techno og es 6(#) 19(%) • MWCNT Process ng Methods 7(#) 23(%) • MWCNT Pur ty 8(#) 26(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 3(#) 10(%) • Other 5(#) 16(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 29(%) • Aggregation/Agg omeration State 11(#) 35(%) • App ed Coatings 12(#) 39(%) • B odegradab ty 6(#) 19(%) • Cata ytic Activ ty 3(#) 10(%) • Charge 6(#) 19(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 8(#) 26(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 29(%) • Pers stence 8(#) 26(%) • Redox Potentia 3(#) 10(%) • S ze/S ze D str bution 10(#) 32(%) • Spec f c Surface Area 7(#) 23(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 10(#) 32(%) • Water So ub ty/D spers b ty 12(#) 39(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 8(#) 26(%) • Groundwater 3(#) 10(%) • Sed ment 4(#) 13(%) • So 7(#) 23(%) • Surface Water 3(#) 10(%) • Wastewater 7(#) 23(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• F ow Regime 0(#) 0(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 1(#) 3(%) • Temperature 3(#) 10(%) • W nd 2(#) 6(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 6(#) 19(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 6(#) 19(%) • Heavy Meta s n Env ronment 1(#) 3(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 1(#) 3(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 1(#) 3(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 3(#) 10(%) • Surfactant (in Lab) 2(#) 6(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 16(%) • B oaccumu ation 5(#) 16(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 2(#) 6(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 23(%) • Chron c Exposure 8(#) 26(%) • Exposure Route 8(#) 26(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 4(#) 13(%) • Human Activ ty 9(#) 29(%) • nd v dua Activ ty Level 9(#) 29(%) • L fe Stage 6(#) 19(%) • Occupation 7(#) 23(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)
13	Disposal/Recycling-Volume	19(#); 61(%)	10(#); 32(%)	2(#); 6(%)	17(#); 55(%)	2(#); 6(%)	0(#); 0(%)	7(#); 23(%)	5(#); 16(%)	7(#); 23(%)	• essential for exposure analysis; proportional to exposure • first principles. • lack of adequate published data on various types of MWCNT • products are too immature for sufficient data • There is an information gap on the likley future level of recycling as it is gradually becoming less commercially and socially acceptable to produce materials which cannot be recycled. Therefore the comparison with decaBDE based flame retardent materials may lead to an under estimation of the volume of recovery and recycling of NT containing flame retardants • While data on how most products get disposed of and recycled is known, the application for MWCNT still isnt known and therefore how MWCNT risk is to be affected by product disposal and recycling is not at all clear. • volume disposed and recycled is vital in order to assess exposure over time and the monitor trends. This depends on the magnitude of products disposed of or recycled	• Analytical Techniques 6(#); 19(%) • Control Technologies 7(#); 23(%) • MWCNT Processing Methods 5(#); 16(%) • MWCNT Purity 5(#); 16(%) • MWCNT Synthesis Methods 4(#); 13(%) • Personal Protective Equipment 6(#); 19(%) • Other 3(#); 10(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 16(%) • Aggregation/Agglomeration State 6(#); 19(%) • Applied Coatings 6(#); 19(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 1(#); 3(%) • Charge 4(#); 13(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 5(#); 16(%) • Matrix Bound vs. Free 6(#); 19(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 19(%) • Persistence 6(#); 19(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 5(#); 16(%) • Specific Surface Area 4(#); 13(%) • Structural Formula/Molecular Structure 5(#); 16(%) • Surface Chemistry 5(#); 16(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 5(#); 16(%) • Groundwater 6(#); 19(%) • Sediment 6(#); 19(%) • Soil 6(#); 19(%) • Surface Water 5(#); 16(%) • Wastewater 6(#); 19(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 3(#); 10(%) • Soil/Sediment Fractionation 4(#); 13(%) • Temperature 3(#); 10(%) • Wind 4(#); 13(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 5(#); 16(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 3(#); 10(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 3(#); 10(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 3(#); 10(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 16(%) • Chronic Exposure 5(#); 16(%) • Exposure Route 4(#); 13(%) • Geographic Location (i.e. rural vs. urban) 3(#); 10(%) • Habitat Structure 4(#); 13(%) • Human Activity 3(#); 10(%) • Individual Activity Level 3(#); 10(%) • Life Stage 3(#); 10(%) • Occupation 3(#); 10(%) • Subchronic Exposure 4(#); 13(%) • Susceptible Populations/Individuals 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
14	D sposa /Recyc ng Release Rate	19(#) 61(%)	10(#) 32(%)	2(#) 6(%)	17(#) 55(%)	2(#) 6(%)	0(#) 0(%)	4(#) 13(%)	4(#) 13(%)	11(#) 35(%)	• essentia for exposure ana ys s proportiona to exposure • f rst pr nc p es • ack of adequate pub shed data on var ous types of MWCNT • tt e data ava ab e s nce arge sca e manufactur ng of CNT coated textiles has not occurred No opportun ties to conduct stud es s nce mater a s are not be d sposed of yet. • Release rates dur ng d sposa and recyc ng processes need to be known n order to assess exposure • Th s w determine the mpact of the vo ume of MWCNT conta n ng products and where MWCNTs are released (dur ng recyc ng n andf s etc) • Unknown release rate/mechan sm for MWCNT f ame retardant upho stery coatings • Wh e data on how most products get d sposed of and recyc ed s known the app cation for MWCNT stil snt known and therefore how MWCNT r sk s to be affected by product d sposa and recyc ng s not at a c ear	• Ana ytica Techn ques 10(#) 32(%) • Contro Techno og es 9(#) 29(%) • MWCNT Process ng Methods 7(#) 23(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 3(#) 10(%) • Persona Protective Equ pment 7(#) 23(%) • Other 3(#) 10(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 23(%) • Aggregation/Agg omeration State 9(#) 29(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 8(#) 26(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 7(#) 23(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 2(#) 6(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 10(#) 32(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 26(%) • Pers stence 8(#) 26(%) • Redox Potentia 2(#) 6(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 7(#) 23(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 9(#) 29(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 29(%) • Groundwater 8(#) 26(%) • Sed ment 9(#) 29(%) • So 10(#) 32(%) • Surface Water 6(#) 19(%) • Wastewater 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 3(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 4(#) 13(%) • So /Sed ment Fractionation 6(#) 19(%) • Temperature 4(#) 13(%) • W nd 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 7(#) 23(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 10(%) • B oaccumu ation 5(#) 16(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 19(%) • Chron c Exposure 6(#) 19(%) • Exposure Route 4(#) 13(%) • Geograph c Location (i.e. rura vs urban) 5(#) 16(%) • Hab tat Structure 4(#) 13(%) • Human Activ ty 5(#) 16(%) • nd v dua Activ ty Level 5(#) 16(%) • L fe Stage 4(#) 13(%) • Occupation 5(#) 16(%) • Subchron c Exposure 4(#) 13(%) • Susceptib e Popu ations/ nd v dua s 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
15	A r Mob ty	28(#) 90(%)	1(#) 3(%)	2(#) 6(%)	24(#) 77(%)	3(#) 10(%)	1(#) 3(%)	5(#) 16(%)	6(#) 19(%)	17(#) 55(%)	• abundant data • aer a d spers on s a concern • w depend on the accumu ation n the ndoor env ronment and what happens to tubes once a rborne or settled/red sturbed • Mob ty vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known • L tt e nformation on a rborne env ronmenta fate once t s released Most kely scenar o for exposure. • No data on CNT release to a r or what happens when they are released • No rea stic stud es and mited data No stud es have descr bed transport of CNTs n a r • shou d rema n on dust	• Ana ytica Techn ques 14(#) 45(%) • Contro Techno og es 6(#) 19(%) • MWCNT Process ng Methods 7(#) 23(%) • MWCNT Pur ty 6(#) 19(%) • MWCNT Synthes s Methods 4(#) 13(%) • Persona Protective Equ pment 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 29(%) • Aggregation/Agg omeration State 16(#) 52(%) • App ed Coatings 8(#) 26(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 5(#) 16(%) • Charge 10(#) 32(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 5(#) 16(%) • Matr x Bound vs Free 15(#) 48(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 11(#) 35(%) • Pers stence 8(#) 26(%) • Redox Potentia 5(#) 16(%) • S ze/S ze D str bution 15(#) 48(%) • Spec f c Surface Area 10(#) 32(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 10(#) 32(%) • Water So ub ty/D spers b ty 7(#) 23(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 35(%) • Groundwater 1(#) 3(%) • Sed ment 1(#) 3(%) • So 2(#) 6(%) • Surface Water 2(#) 6(%) • Wastewater 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 7(#) 23(%) • L ght Ava ab ty 3(#) 10(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 1(#) 3(%) • Temperature 6(#) 19(%) • W nd 12(#) 39(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 4(#) 13(%) • pH 1(#) 3(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 6(%) • B oaccumu ation 3(#) 10(%) • B omagn f cation 2(#) 6(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 1(#) 3(%) • Spec es/ nd v dua Developmenta Behav or 0(#) 0(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 6(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 16(%) • Chron c Exposure 7(#) 23(%) • Exposure Route 6(#) 19(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 4(#) 13(%) • L fe Stage 3(#) 10(%) • Occupation 3(#) 10(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
16	A r Pers stence	28(#) 90(%)	1(#) 3(%)	2(#) 6(%)	17(#) 55(%)	8(#) 26(%)	3(#) 10(%)	8(#) 26(%)	5(#) 16(%)	15(#) 48(%)	• abundant data • aer a d spers on s a concern potentia for photoactivation/degredation/etc • We know that MWCNT are very pers stent • Accumu ation n areas wou d be s gn f cant; mportant to estimate potentia dose • mited nformation and few stud es • Bu d up • Pers stance vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known	• Ana ytica Techn ques 12(#) 39(%) • Contro Techno og es 8(#) 26(%) • MWCNT Process ng Methods 9(#) 29(%) • MWCNT Pur ty 7(#) 23(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 32(%) • Aggregation/Agg omeration State 13(#) 42(%) • App ed Coatings 9(#) 29(%) • B odegradab ty 10(#) 32(%) • Cata ytic Activ ty 6(#) 19(%) • Charge 10(#) 32(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 13(#) 42(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 11(#) 35(%) • Pers stence 12(#) 39(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 10(#) 32(%) • Spec f c Surface Area 8(#) 26(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 9(#) 29(%) • Water So ub ty/D spers b ty 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 29(%) • Groundwater 0(#) 0(%) • Sed ment 0(#) 0(%) • So 3(#) 10(%) • Surface Water 3(#) 10(%) • Wastewater 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 5(#) 16(%) • L ght Ava ab ty 4(#) 13(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 4(#) 13(%) • W nd 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 3(#) 10(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 4(#) 13(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 3(#) 10(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 13(%) • B oaccumu ation 4(#) 13(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 4(#) 13(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 13(%) • Chron c Exposure 5(#) 16(%) • Exposure Route 4(#) 13(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 5(#) 16(%) • nd v dua Activ ty Level 5(#) 16(%) • L fe Stage 4(#) 13(%) • Occupation 4(#) 13(%) • Subchron c Exposure 5(#) 16(%) • Susceptib e Popu ations/ nd v dua s 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
17	A r B oava ab ty	28(#) 90(%)	1(#) 3(%)	2(#) 6(%)	18(#) 58(%)	8(#) 26(%)	2(#) 6(%)	4(#) 13(%)	5(#) 16(%)	19(#) 61(%)	• abundant data • aer a d spers on s a concern potentia exposure to a r breath ng organ sms h gh • B oava ab ty vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known • mited nformation and stud es • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • w depend on the partic e s ze; most nha ab e s ze fraction and and agg omeration vs s ng e f ber fate	• Ana ytica Techn ques 12(#) 39(%) • Contro Techno og es 6(#) 19(%) • MWCNT Process ng Methods 8(#) 26(%) • MWCNT Pur ty 10(#) 32(%) • MWCNT Synthes s Methods 5(#) 16(%) • Persona Protective Equ pment 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 39(%) • Aggregation/Agg omeration State 15(#) 48(%) • App ed Coatings 12(#) 39(%) • B odegradab ty 10(#) 32(%) • Cata ytic Activ ty 7(#) 23(%) • Charge 11(#) 35(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 5(#) 16(%) • L poph c ty 11(#) 35(%) • Matr x Bound vs Free 13(#) 42(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 11(#) 35(%) • Pers stence 12(#) 39(%) • Redox Potentia 7(#) 23(%) • S ze/S ze D str bution 12(#) 39(%) • Spec f c Surface Area 11(#) 35(%) • Structura Formu a/Mo ecu ar Structure 8(#) 26(%) • Surface Chem stry 13(#) 42(%) • Water So ub ty/D spers b ty 10(#) 32(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 2(#) 6(%) • Sed ment 2(#) 6(%) • So 3(#) 10(%) • Surface Water 3(#) 10(%) • Wastewater 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 13(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 3(#) 10(%) • W nd 7(#) 23(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 6(#) 19(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 3(#) 10(%) • on c Strength n Env ronment 5(#) 16(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 3(#) 10(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 4(#) 13(%) • Surfactant (in Lab) 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 19(%) • B oaccumu ation 7(#) 23(%) • B omagn f cation 5(#) 16(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 6(#) 19(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 19(%) • Chron c Exposure 8(#) 26(%) • Exposure Route 8(#) 26(%) • Geograph c Location (i.e. rura vs urban) 6(#) 19(%) • Hab tat Structure 4(#) 13(%) • Human Activ ty 10(#) 32(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 6(#) 19(%) • Occupation 6(#) 19(%) • Subchron c Exposure 6(#) 19(%) • Susceptib e Popu ations/ nd v dua s 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
18	Surface Water Mob ty	13(#) 42(%)	8(#) 26(%)	10(#) 32(%)	12(#) 39(%)	1(#) 3(%)	0(#) 0(%)	3(#) 10(%)	4(#) 13(%)	6(#) 19(%)	• SW may be ma or d str bution route • th s can be tested more d rectly data and ana ytica methodo ogy ack ng • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • We know that MWCNT are very pers stent • SW may be ma or d str bution route • Few stud es are ava ab e on th s top c but MWCNTs are expected to be fa r y res stant to degradation • data and ana ytica methodo ogy ack ng
19	Surface Water Pers stence	13(#) 42(%)	8(#) 26(%)	10(#) 32(%)	9(#) 29(%)	4(#) 13(%)	0(#) 0(%)	3(#) 10(%)	4(#) 13(%)	6(#) 19(%)	• SW may be ma or d str bution route • We know that MWCNT are very pers stent • Few stud es are ava ab e on th s top c but MWCNTs are expected to be fa r y res stant to degradation • data and ana ytica methodo ogy ack ng
20	Surface Water B oava ab ty	13(#) 42(%)	8(#) 26(%)	10(#) 32(%)	10(#) 32(%)	3(#) 10(%)	0(#) 0(%)	2(#) 6(%)	3(#) 10(%)	8(#) 26(%)	• SW may be ma or d str bution route; potentia uptake, accumu ation and foodcha n transfer n aquatic organ sms nc ud ng p ants • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • data and ana ytica methodo ogy ack ng • ngestion by organ sms w kely mpact transport and a so s kely to ncrease agg omeration and settling out of so ution

ID	Influential Factors						
	Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
18	• Ana ytica Techn ques 6(#) 19(%) • Contro Techno og es 5(#) 16(%) • MWCNT Process ng Methods 4(#) 13(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 3(#) 10(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 23(%) • Aggregation/Agg omeration State 7(#) 23(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 3(#) 10(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 6(#) 19(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 6(#) 19(%) • Pers stence 2(#) 6(%) • Redox Potentia 2(#) 6(%) • S ze/S ze D str bution 6(#) 19(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 5(#) 16(%) • Surface Chem stry 6(#) 19(%) • Water So ub ty/D spers b ty 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 6(%) • Groundwater 2(#) 6(%) • Sed ment 4(#) 13(%) • So 4(#) 13(%) • Surface Water 6(#) 19(%) • Wastewater 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 5(#) 16(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 4(#) 13(%) • W nd 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 7(#) 23(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 5(#) 16(%) • on c Strength n Env ronment 8(#) 26(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 8(#) 26(%) • Other Contaminants n Env ronment 6(#) 19(%) • pH 5(#) 16(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 7(#) 23(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 6(%) • B oaccumu ation 4(#) 13(%) • B omagn f cation 4(#) 13(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 3(%) • Chron c Exposure 4(#) 13(%) • Exposure Route 4(#) 13(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 6(#) 19(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 1(#) 3(%) • Occupation 1(#) 3(%) • Subchron c Exposure 3(#) 10(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
19	• Ana ytica Techn ques 5(#) 16(%) • Contro Techno og es 5(#) 16(%) • MWCNT Process ng Methods 4(#) 13(%) • MWCNT Pur ty 2(#) 6(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 5(#) 16(%) • App ed Coatings 5(#) 16(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 5(#) 16(%) • Matr x Bound vs Free 5(#) 16(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 13(%) • Pers stence 4(#) 13(%) • Redox Potentia 2(#) 6(%) • S ze/S ze D str bution 5(#) 16(%) • Spec f c Surface Area 4(#) 13(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 6(%) • Groundwater 3(#) 10(%) • Sed ment 3(#) 10(%) • So 4(#) 13(%) • Surface Water 5(#) 16(%) • Wastewater 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 2(#) 6(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 2(#) 6(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 5(#) 16(%) • L gand Concentrations n Env ronment 4(#) 13(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 4(#) 13(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 4(#) 13(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 6(%) • Chron c Exposure 4(#) 13(%) • Exposure Route 3(#) 10(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 2(#) 6(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 1(#) 3(%) • Occupation 1(#) 3(%) • Subchron c Exposure 2(#) 6(%) • Susceptib e Popu ations/ nd v dua s 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
20	• Ana ytica Techn ques 7(#) 23(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 19(%) • Aggregation/Agg omeration State 7(#) 23(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 6(#) 19(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 4(#) 13(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 8(#) 26(%) • Matr x Bound vs Free 7(#) 23(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 6(#) 19(%) • Pers stence 5(#) 16(%) • Redox Potentia 2(#) 6(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 3(#) 10(%) • Surface Chem stry 7(#) 23(%) • Water So ub ty/D spers b ty 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 6(%) • Groundwater 3(#) 10(%) • Sed ment 2(#) 6(%) • So 3(#) 10(%) • Surface Water 4(#) 13(%) • Wastewater 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 2(#) 6(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 5(#) 16(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 7(#) 23(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 6(#) 19(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 7(#) 23(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 5(#) 16(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 6(%) • Chron c Exposure 4(#) 13(%) • Exposure Route 3(#) 10(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 2(#) 6(%) • Human Activ ty 4(#) 13(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 2(#) 6(%) • Occupation 1(#) 3(%) • Subchron c Exposure 2(#) 6(%) • Susceptib e Popu ations/ nd v dua s 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
21	Groundwater-Mobility	5(#); 16(%)	12(#); 39(%)	14(#); 45(%)	5(#); 16(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 6(%)	3(#); 10(%)	• lack of repeatability in data	• Analytical Techniques 1(#); 3(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 2(#); 6(%) • Applied Coatings 2(#); 6(%) • Biodegradability 1(#); 3(%) • Catalytic Activity 1(#); 3(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 6(%) • Matrix Bound vs. Free 2(#); 6(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 6(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 1(#); 3(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 6(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 2(#); 6(%) • pH 1(#); 3(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 2(#); 6(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 1(#); 3(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 3(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
22	Groundwater-Persistence	5(#); 16(%)	12(#); 39(%)	14(#); 45(%)	4(#); 13(%)	1(#); 3(%)	0(#); 0(%)	0(#); 0(%)	2(#); 6(%)	3(#); 10(%)	• lack of repeatability in data	• Analytical Techniques 1(#); 3(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 1(#); 3(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 3(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 3(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 3(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 0(#); 0(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
23	Groundwater-Bioavailability	5(#); 16(%)	12(#); 39(%)	14(#); 45(%)	1(#); 3(%)	3(#); 10(%)	1(#); 3(%)	0(#); 0(%)	2(#); 6(%)	3(#); 10(%)	• lack of repeatability in data	• Analytical Techniques 1(#); 3(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 1(#); 3(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 3(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 3(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 3(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 0(#); 0(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
24	Wastewater Mob ty	18(#) 58(%)	9(#) 29(%)	4(#) 13(%)	17(#) 55(%)	1(#) 3(%)	0(#) 0(%)	3(#) 10(%)	5(#) 16(%)	10(#) 32(%)	• antic pated ma or source of MWNT • Data not ava ab e on mob ty of MWCNTs n wastewater Few stud es descr be MWCNT remova by wastewater treatment processes • kely to accumu ate n wastewater s mater a co ected from eff uent? • mited nformation ack of comprehens ve data	• Ana ytica Techn ques 8(#) 26(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 11(#) 35(%) • Aggregation/Agg omeration State 11(#) 35(%) • App ed Coatings 9(#) 29(%) • B odegradab ty 9(#) 29(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 4(#) 13(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 9(#) 29(%) • Matr x Bound vs Free 11(#) 35(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 26(%) • Pers stence 6(#) 19(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 5(#) 16(%) • Surface Chem stry 11(#) 35(%) • Water So ub ty/D spers b ty 10(#) 32(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 3(%) • Groundwater 3(#) 10(%) • Sed ment 2(#) 6(%) • So 4(#) 13(%) • Surface Water 2(#) 6(%) • Wastewater 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 7(#) 23(%) • L ght Ava ab ty 3(#) 10(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 3(#) 10(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 5(#) 16(%) • D spers ng Agents 7(#) 23(%) • D sso ved Oxygen Content 5(#) 16(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 7(#) 23(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 8(#) 26(%) • Other Contaminants n Env ronment 6(#) 19(%) • pH 6(#) 19(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 6(#) 19(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 2(#) 6(%) • B omagn f cation 2(#) 6(%) • M crob a Commun ties n Env ronment 5(#) 16(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 6(%) • Chron c Exposure 2(#) 6(%) • Exposure Route 2(#) 6(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 4(#) 13(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 0(#) 0(%) • Occupation 1(#) 3(%) • Subchron c Exposure 3(#) 10(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
25	Wastewater Pers stence	18(#) 58(%)	9(#) 29(%)	4(#) 13(%)	15(#) 48(%)	2(#) 6(%)	1(#) 3(%)	5(#) 16(%)	3(#) 10(%)	10(#) 32(%)	• We know that MWCNT are very pers stent • Comp ex b o og ca med a w th mu tip epotentia b o og ca /phys ca routes of transformation • kely to accumu ate n wastewater s mater a co ected from eff uent? • Data not ava ab e on pers stence of MWCNTs n wastewater • t s un kely for substantia degradation to occur based on the short time n wastewater treatment p ants • ack of comprehens ve data	• Ana ytica Techn ques 5(#) 16(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 26(%) • Aggregation/Agg omeration State 8(#) 26(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 7(#) 23(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 4(#) 13(%) • Conductive or Magnetic Properties 3(#) 10(%) • Crysta ne Phase 2(#) 6(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 8(#) 26(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 13(%) • Pers stence 8(#) 26(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 5(#) 16(%) • Spec f c Surface Area 4(#) 13(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 3(%) • Groundwater 2(#) 6(%) • Sed ment 3(#) 10(%) • So 3(#) 10(%) • Surface Water 3(#) 10(%) • Wastewater 7(#) 23(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 5(#) 16(%) • L ght Ava ab ty 3(#) 10(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 5(#) 16(%) • Temperature 4(#) 13(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 5(#) 16(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 4(#) 13(%) • Natura Organ c Matter (NOM) 7(#) 23(%) • Other Contaminants n Env ronment 6(#) 19(%) • pH 5(#) 16(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 2(#) 6(%) • B omagn f cation 2(#) 6(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 3(%) • Chron c Exposure 2(#) 6(%) • Exposure Route 2(#) 6(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 2(#) 6(%) • nd v dua Activ ty Level 1(#) 3(%) • L fe Stage 1(#) 3(%) • Occupation 0(#) 0(%) • Subchron c Exposure 2(#) 6(%) • Susceptib e Popu ations/ nd v dua s 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
26	Wastewater B oava ab ty	18(#) 58(%)	9(#) 29(%)	4(#) 13(%)	11(#) 35(%)	7(#) 23(%)	0(#) 0(%)	2(#) 6(%)	4(#) 13(%)	12(#) 39(%)	• M crobes and microb a b of ms must mportant and probab e organ sms of concern n WWTP • L tt e data ava ab e on b oava ab ty of MWCNT forms for f ame retardants n wastewater • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • nteractions w th activated s udge and microorgan sms w kely mpact the remova rates before release nto water systems a though nteractions w th s udge can ead to and app cation • mited evel of microb stud es s ava ab e. • most kely b oava ab e to benth c organ sms	• Ana ytica Techn ques 7(#) 23(%) • Contro Techno og es 5(#) 16(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 1(#) 3(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 29(%) • Aggregation/Agg omeration State 9(#) 29(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 7(#) 23(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 4(#) 13(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 8(#) 26(%) • Matr x Bound vs Free 9(#) 29(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 6(#) 19(%) • Pers stence 6(#) 19(%) • Redox Potentia 3(#) 10(%) • S ze/S ze D str bution 6(#) 19(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 9(#) 29(%) • Water So ub ty/D spers b ty 8(#) 26(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 2(#) 6(%) • Sed ment 1(#) 3(%) • So 3(#) 10(%) • Surface Water 2(#) 6(%) • Wastewater 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 13(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 5(#) 16(%) • Temperature 3(#) 10(%) • W nd 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 6(#) 19(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 5(#) 16(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 8(#) 26(%) • Other Contaminants n Env ronment 6(#) 19(%) • pH 6(#) 19(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 6(#) 19(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 3(#) 10(%) • B omagn f cation 2(#) 6(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 2(#) 6(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 10(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 6(%) • Chron c Exposure 2(#) 6(%) • Exposure Route 1(#) 3(%) • Geograph c Location (i.e. rura vs urban) 1(#) 3(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 2(#) 6(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 1(#) 3(%) • Occupation 0(#) 0(%) • Subchron c Exposure 1(#) 3(%) • Susceptib e Popu ations/ nd v dua s 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
27	Sediment-Mobility	11(#); 35(%)	14(#); 45(%)	6(#); 19(%)	5(#); 16(%)	3(#); 10(%)	3(#); 10(%)	0(#); 0(%)	4(#); 13(%)	7(#); 23(%)	• Our knowledge about the mobility of MWCNT is very limited and why do not know whether the test methods we use to assess mobility of regular chemical are approrpiate • Low solubility in water will limit mobility unless functionalized • Studies assessing sorption of MWCNTs to soils will likely also be applicable to sediments	• Analytical Techniques 5(#); 16(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 4(#); 13(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 4(#); 13(%) • Applied Coatings 4(#); 13(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 2(#); 6(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 3(#); 10(%) • Matrix Bound vs. Free 5(#); 16(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 2(#); 6(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 5(#); 16(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 1(#); 3(%) • Sediment 2(#); 6(%) • Soil 2(#); 6(%) • Surface Water 1(#); 3(%) • Wastewater 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 2(#); 6(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 2(#); 6(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 4(#); 13(%) • Dissolved Oxygen Content 2(#); 6(%) • Exposure to Sunlight 3(#); 10(%) • Heavy Metals in Environment 4(#); 13(%) • Ionic Strength in Environment 4(#); 13(%) • Ligand Concentrations in Environment 3(#); 10(%) • Natural Organic Matter (NOM) 5(#); 16(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 3(#); 10(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 2(#); 6(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
28	Sediment-Persistence	11(#); 35(%)	14(#); 45(%)	6(#); 19(%)	10(#); 32(%)	1(#); 3(%)	0(#); 0(%)	1(#); 3(%)	3(#); 10(%)	7(#); 23(%)	• We know that MWCNT are very persistent • Will affect length of exposure • Degradation of MWCNTs in sediments is likely to be very slow	• Analytical Techniques 6(#); 19(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 19(%) • Aggregation/Agglomeration State 4(#); 13(%) • Applied Coatings 6(#); 19(%) • Biodegradability 6(#); 19(%) • Catalytic Activity 3(#); 10(%) • Charge 3(#); 10(%) • Conductive or Magnetic Properties 3(#); 10(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 5(#); 16(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 7(#); 23(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 5(#); 16(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 2(#); 6(%) • Sediment 5(#); 16(%) • Soil 4(#); 13(%) • Surface Water 2(#); 6(%) • Wastewater 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 2(#); 6(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 4(#); 13(%) • Temperature 2(#); 6(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 3(#); 10(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 3(#); 10(%) • Heavy Metals in Environment 4(#); 13(%) • Ionic Strength in Environment 3(#); 10(%) • Ligand Concentrations in Environment 3(#); 10(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 2(#); 6(%) • pH 2(#); 6(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 2(#); 6(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 3(#); 10(%) • Biomagnification 3(#); 10(%) • Microbial Communities in Environment 3(#); 10(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 1(#); 3(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
29	Sediment-Bioavailability	11(#); 35(%)	14(#); 45(%)	6(#); 19(%)	10(#); 32(%)	1(#); 3(%)	0(#); 0(%)	0(#); 0(%)	3(#); 10(%)	8(#); 26(%)	• We know that MWCNT are very persistent • Will affect length of exposure • Degradation of MWCNTs in sediments is likely to be very slow	• Analytical Techniques 7(#); 23(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 3(#); 10(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 7(#); 23(%) • Aggregation/Agglomeration State 5(#); 16(%) • Applied Coatings 7(#); 23(%) • Biodegradability 7(#); 23(%) • Catalytic Activity 2(#); 6(%) • Charge 3(#); 10(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 7(#); 23(%) • Matrix Bound vs. Free 6(#); 19(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 16(%) • Persistence 5(#); 16(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 6(#); 19(%) • Water Solubility/Dispersibility 6(#); 19(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 1(#); 3(%) • Sediment 4(#); 13(%) • Soil 3(#); 10(%) • Surface Water 1(#); 3(%) • Wastewater 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 2(#); 6(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 5(#); 16(%) • Temperature 2(#); 6(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 4(#); 13(%) • Dissolved Oxygen Content 2(#); 6(%) • Exposure to Sunlight 3(#); 10(%) • Heavy Metals in Environment 5(#); 16(%) • Ionic Strength in Environment 4(#); 13(%) • Ligand Concentrations in Environment 4(#); 13(%) • Natural Organic Matter (NOM) 5(#); 16(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 3(#); 10(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 4(#); 13(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 2(#); 6(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
30	So Mob ty	13(#) 42(%)	10(#) 32(%)	8(#) 26(%)	7(#) 23(%)	4(#) 13(%)	2(#) 6(%)	2(#) 6(%)	3(#) 10(%)	8(#) 26(%)	• nformation mited p 3 12 12 • Native vs functiona zed form w affect b oava ab ty • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • A number of stud es have shown mited b oaccumu ation of MWCNTs by sed ment organ sms a though b oturbation and mixing of MWCNTs n sed ments by organ sms cou d occur	• Ana ytica Techn ques 5(#) 16(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 2(#) 6(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 1(#) 3(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 5(#) 16(%) • App ed Coatings 5(#) 16(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 1(#) 3(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 4(#) 13(%) • Matr x Bound vs Free 5(#) 16(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 3(#) 10(%) • Redox Potentia 1(#) 3(%) • S ze/S ze D str bution 4(#) 13(%) • Spec f c Surface Area 4(#) 13(%) • Structura Formu a/Mo ecu ar Structure 2(#) 6(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 0(#) 0(%) • Sed ment 0(#) 0(%) • So 2(#) 6(%) • Surface Water 0(#) 0(%) • Wastewater 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 3(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 2(#) 6(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 2(#) 6(%) • Exposure to Sun ght 2(#) 6(%) • Heavy Meta s n Env ronment 2(#) 6(%) • on c Strength n Env ronment 2(#) 6(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 3(#) 10(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#) 0(%) • B oaccumu ation 1(#) 3(%) • B omagn f cation 1(#) 3(%) • M crob a Commun ties n Env ronment 1(#) 3(%) • Organ sm Hea th 1(#) 3(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 3(%) • Spec es/ nd v dua Feed ng Behav or 1(#) 3(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 3(%) • Chron c Exposure 1(#) 3(%) • Exposure Route 1(#) 3(%) • Geograph c Location (i.e. rura vs urban) 1(#) 3(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 2(#) 6(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupation 1(#) 3(%) • Subchron c Exposure 1(#) 3(%) • Susceptib e Popu ations/ nd v dua s 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
31	So Pers stence	13(#) 42(%)	10(#) 32(%)	8(#) 26(%)	12(#) 39(%)	1(#) 3(%)	0(#) 0(%)	3(#) 10(%)	3(#) 10(%)	7(#) 23(%)	• so app cation of WWTP s udge kely route for MWNTs to get to so So :water partition ng key to transport a ong w th eroded so • data and ana ytica methodo ogy ack ng nformation mited p 3 14 15 • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • A number of stud es have nvestigated sorption to so minera components as wel as transport n porous med a • nsuff c ent data ava ab e for MWCNT so mob ty • Low so ub ty n water w mit mob ty un ess functiona zed	• Ana ytica Techn ques 5(#) 16(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 1(#) 3(%) • MWCNT Pur ty 2(#) 6(%) • MWCNT Synthes s Methods 0(#) 0(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 4(#) 13(%) • App ed Coatings 5(#) 16(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 1(#) 3(%) • Charge 2(#) 6(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 4(#) 13(%) • Matr x Bound vs Free 5(#) 16(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 13(%) • Pers stence 4(#) 13(%) • Redox Potentia 1(#) 3(%) • S ze/S ze D str bution 4(#) 13(%) • Spec f c Surface Area 2(#) 6(%) • Structura Formu a/Mo ecu ar Structure 1(#) 3(%) • Surface Chem stry 4(#) 13(%) • Water So ub ty/D spers b ty 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 1(#) 3(%) • Sed ment 1(#) 3(%) • So 3(#) 10(%) • Surface Water 1(#) 3(%) • Wastewater 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 3(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 2(#) 6(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 3(#) 10(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 1(#) 3(%) • on c Strength n Env ronment 1(#) 3(%) • L gand Concentrations n Env ronment 1(#) 3(%) • Natura Organ c Matter (NOM) 2(#) 6(%) • Other Contaminants n Env ronment 2(#) 6(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 1(#) 3(%) • Sa n ty 1(#) 3(%) • Surfactant (in Lab) 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 1(#) 3(%) • B omagn f cation 1(#) 3(%) • M crob a Commun ties n Env ronment 1(#) 3(%) • Organ sm Hea th 1(#) 3(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 3(%) • Spec es/ nd v dua Feed ng Behav or 1(#) 3(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 3(%) • Chron c Exposure 1(#) 3(%) • Exposure Route 1(#) 3(%) • Geograph c Location (i.e. rura vs urban) 1(#) 3(%) • Hab tat Structure 1(#) 3(%) • Human Activ ty 1(#) 3(%) • nd v dua Activ ty Level 1(#) 3(%) • L fe Stage 0(#) 0(%) • Occupation 1(#) 3(%) • Subchron c Exposure 1(#) 3(%) • Susceptib e Popu ations/ nd v dua s 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
32	So B oava ab ty	13(#) 42(%)	10(#) 32(%)	8(#) 26(%)	12(#) 39(%)	1(#) 3(%)	0(#) 0(%)	2(#) 6(%)	2(#) 6(%)	9(#) 29(%)	• Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • potentia uptake and accuu ation n so microorgan sms nvertebrates and p ants • data and ana ytica methodo ogy ack ng nformation mited p 3 14 15 nsuff c ent data ava ab e for MWCNT so b oava ab ty • Native vs functiona zed form w affect b oava ab ty • Severa stud es have shown mited b oaccumu ation of MWCNTs by earthworms a though tt e data s ava ab e for other so organ sms	• Ana ytica Techn ques 6(#) 19(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 1(#) 3(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 0(#) 0(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 19(%) • Aggregation/Agg omeration State 5(#) 16(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 6(#) 19(%) • Cata ytic Activ ty 1(#) 3(%) • Charge 2(#) 6(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 5(#) 16(%) • Matr x Bound vs Free 6(#) 19(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 4(#) 13(%) • Redox Potentia 1(#) 3(%) • S ze/S ze D str bution 5(#) 16(%) • Spec f c Surface Area 3(#) 10(%) • Structura Formu a/Mo ecu ar Structure 1(#) 3(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 0(#) 0(%) • Sed ment 1(#) 3(%) • So 3(#) 10(%) • Surface Water 0(#) 0(%) • Wastewater 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 3(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 2(#) 6(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 2(#) 6(%) • Exposure to Sun ght 2(#) 6(%) • Heavy Meta s n Env ronment 2(#) 6(%) • on c Strength n Env ronment 2(#) 6(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 3(#) 10(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 3(#) 10(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 3(%) • B oaccumu ation 3(#) 10(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 2(#) 6(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 6(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 6(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 3(%) • Chron c Exposure 1(#) 3(%) • Exposure Route 1(#) 3(%) • Geograph c Location (i.e. rura vs urban) 0(#) 0(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 1(#) 3(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 1(#) 3(%) • Occupation 0(#) 0(%) • Subchron c Exposure 1(#) 3(%) • Susceptib e Popu ations/ nd v dua s 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
33	B ota B oaccumu ation	14(#) 45(%)	14(#) 45(%)	3(#) 10(%)	13(#) 42(%)	1(#) 3(%)	0(#) 0(%)	1(#) 3(%)	5(#) 16(%)	8(#) 26(%)	• Lack of nformation no rel ab e stud es • Our know edge about the b oaccumu ation of MWCNT s very mited and why do not know whether the test methods we use to assess b oaccumu ation of regu ar chem ca are approrp ate • ncomp ete data on accumu ation of MWCNT n b ota • where does mater a b oaccumu ate f exposure was not a rborne? • Numerous stud es have shown mited b oaccumu ation by a range of mu ticel u ar organ sms but ess s known about the el mination rates and about uptake by un cel u ar organ sms or food cha n transfer	• Ana ytica Techn ques 7(#) 23(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 23(%) • Aggregation/Agg omeration State 9(#) 29(%) • App ed Coatings 9(#) 29(%) • B odegradab ty 7(#) 23(%) • Cata ytic Activ ty 1(#) 3(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 9(#) 29(%) • Matr x Bound vs Free 9(#) 29(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 7(#) 23(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 8(#) 26(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 3(#) 10(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 7(#) 23(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• A r 4(#) 13(%) • Groundwater 3(#) 10(%) • Sed ment 4(#) 13(%) • So 5(#) 16(%) • Surface Water 5(#) 16(%) • Wastewater 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 2(#) 6(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 6(#) 19(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 7(#) 23(%) • Protein Concentration n Env ronment 7(#) 23(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 19(%) • B oaccumu ation 8(#) 26(%) • B omagn f cation 8(#) 26(%) • M crob a Commun ties n Env ronment 8(#) 26(%) • Organ sm Hea th 6(#) 19(%) • Spec es/ nd v dua Developmenta Behav or 6(#) 19(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 6(%) • Chron c Exposure 6(#) 19(%) • Exposure Route 6(#) 19(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 3(#) 10(%) • L fe Stage 4(#) 13(%) • Occupation 3(#) 10(%) • Subchron c Exposure 5(#) 16(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
34	Human: Occupational-Ingestion	30(#); 97(%)	1(#); 3(%)	0(#); 0(%)	6(#); 19(%)	14(#); 45(%)	10(#); 32(%)	4(#); 13(%)	12(#); 39(%)	14(#); 45(%)	• Lack of experimental data; conflicting results; Insufficient studies, only inferring possible inhalation pathway p 4-20-21; Incomplete data available for specifie MWCNT forms. • For occupational, once you know the exposure routes and PPE in place, you can quickly rule this out. Ingestion is typically never an issue for occupational exposure risk. • least probable exposure route and unlikely • Ingestion has not been well studied in terms of MWCNT exposures. Risk due to exposure is still not known • In terms of exposure routes for particulates in the ocupational setting, ingestion is relativly unlikely although ingestion secondary to inhalation exposure (i.e. swallowing of material from the lung cleared by the mucocillary escalator) of due to had to • Especially for liquid applications for CNT dried spray or splatter can easily be transferred from hand to mouth	• Analytical Techniques 8(#); 26(%) • Control Technologies 10(#); 32(%) • MWCNT Processing Methods 9(#); 29(%) • MWCNT Purity 7(#); 23(%) • MWCNT Synthesis Methods 8(#); 26(%) • Personal Protective Equipment 10(#); 32(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 9(#); 29(%) • Aggregation/Agglomeration State 8(#); 26(%) • Applied Coatings 9(#); 29(%) • Biodegradability 6(#); 19(%) • Catalytic Activity 3(#); 10(%) • Charge 6(#); 19(%) • Conductive or Magnetic Properties 3(#); 10(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 7(#); 23(%) • Matrix Bound vs. Free 9(#); 29(%) • Morphology (e.g. aspect ratio, length, width, shape) 8(#); 26(%) • Persistence 7(#); 23(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 8(#); 26(%) • Specific Surface Area 7(#); 23(%) • Structural Formula/Molecular Structure 6(#); 19(%) • Surface Chemistry 8(#); 26(%) • Water Solubility/Dispersibility 7(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 10(%) • Groundwater 3(#); 10(%) • Sediment 1(#); 3(%) • Soil 2(#); 6(%) • Surface Water 4(#); 13(%) • Wastewater 2(#); 6(%) • Other 2(#); 6(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 4(#); 13(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 8(#); 26(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 6(#); 19(%) • Ionic Strength in Environment 6(#); 19(%) • Ligand Concentrations in Environment 5(#); 16(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 8(#); 26(%) • pH 6(#); 19(%) • Protein Concentration in Environment 6(#); 19(%) • Salinity 4(#); 13(%) • Surfactant (in Lab) 6(#); 19(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 7(#); 23(%) • Bioaccumulation 7(#); 23(%) • Biomagnification 5(#); 16(%) • Microbial Communities in Environment 4(#); 13(%) • Organism Health 6(#); 19(%) • Species/Individual Developmental Behavior 4(#); 13(%) • Species/Individual Feeding Behavior 7(#); 23(%) • Species/Individual Reproductive Behavior 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 10(#); 32(%) • Chronic Exposure 11(#); 35(%) • Exposure Route 11(#); 35(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 2(#); 6(%) • Human Activity 9(#); 29(%) • Individual Activity Level 8(#); 26(%) • Life Stage 6(#); 19(%) • Occupation 9(#); 29(%) • Subchronic Exposure 10(#); 32(%) • Susceptible Populations/Individuals 9(#); 29(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
35	Human: Occupational-Inhalation	30(#); 97(%)	1(#); 3(%)	0(#); 0(%)	30(#); 97(%)	0(#); 0(%)	0(#); 0(%)	8(#); 26(%)	12(#); 39(%)	10(#); 32(%)	• abundant animal data; Animal data supportive of a respiratory disease risk • probable exposure route • Some data seems to exist already on inhalation risk provided by raw nanotubes • we have sufficient data to qualitatively assess inhalation exposure. quantitation and exposure limits are still crude • clear risks, but conflicting results thus far; few true inhalation studies • Inhalation is the main route of exposure during production, but there is limited data on real time exposure levels • Insufficient studies, only inferring possible inhalation pathway p 4-20-21; lack of experimential data; Some studies have been conducted on this pathway mainly for laboratory settings but many processes such as recycling have not been studied • Challenges in measurement methods and lack of adequate characterisation of aerosols (e.g. reporting of mass based metrics rather than size distributions, morphologies etc) and indeed the lack of scientific data of exposure level during various work activity • Most likely form of exposure, but if applied wet should not produce much of a exposure concern.	• Analytical Techniques 14(#); 45(%) • Control Technologies 18(#); 58(%) • MWCNT Processing Methods 14(#); 45(%) • MWCNT Purity 11(#); 35(%) • MWCNT Synthesis Methods 12(#); 39(%) • Personal Protective Equipment 18(#); 58(%) • Other 2(#); 6(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 9(#); 29(%) • Aggregation/Agglomeration State 16(#); 52(%) • Applied Coatings 15(#); 48(%) • Biodegradability 8(#); 26(%) • Catalytic Activity 4(#); 13(%) • Charge 11(#); 35(%) • Conductive or Magnetic Properties 4(#); 13(%) • Crystalline Phase 5(#); 16(%) • Lipophilicity 7(#); 23(%) • Matrix Bound vs. Free 16(#); 52(%) • Morphology (e.g. aspect ratio, length, width, shape) 16(#); 52(%) • Persistence 13(#); 42(%) • Redox Potential 4(#); 13(%) • Size/Size Distribution 16(#); 52(%) • Specific Surface Area 11(#); 35(%) • Structural Formula/Molecular Structure 8(#); 26(%) • Surface Chemistry 14(#); 45(%) • Water Solubility/Dispersibility 8(#); 26(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 14(#); 45(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 4(#); 13(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 3(#); 10(%) • Wind 6(#); 19(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 7(#); 23(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 6(#); 19(%) • Ionic Strength in Environment 3(#); 10(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 7(#); 23(%) • pH 3(#); 10(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 3(#); 10(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 9(#); 29(%) • Bioaccumulation 8(#); 26(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 5(#); 16(%) • Species/Individual Developmental Behavior 5(#); 16(%) • Species/Individual Feeding Behavior 3(#); 10(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 16(#); 52(%) • Chronic Exposure 18(#); 58(%) • Exposure Route 15(#); 48(%) • Geographic Location (i.e. rural vs. urban) 4(#); 13(%) • Habitat Structure 1(#); 3(%) • Human Activity 14(#); 45(%) • Individual Activity Level 14(#); 45(%) • Life Stage 8(#); 26(%) • Occupation 15(#); 48(%) • Subchronic Exposure 15(#); 48(%) • Susceptible Populations/Individuals 10(#); 32(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
36	Human: Occupational-Dermal	30(#); 97(%)	1(#); 3(%)	0(#); 0(%)	8(#); 26(%)	12(#); 39(%)	10(#); 32(%)	6(#); 19(%)	10(#); 32(%)	14(#); 45(%)	• Conservative Importance and Confidence ratings for this E-RRF pair were added by RTI because the participant had not selected ratings for this E-RRF pair, but completed the rest of the CEA MWCNT Prioritization Tool. • Whilst sampling of dermal exposure (e.g. using wipes after a task followed by quantification of CNT and characterisation) is arguably much more straight forward than for aerosol measurements, there is still a considerable lack of scientific data of dermal • the overwhelming data indicate that dermal exposure is of little systemic importance. • Limited exposure and toxicity potential; no reliable studies • not a likely route • Dermal exposure does not seem to be a risk; potential exposure route but low probability • Little to no work done on dermal exposures in workplace- are dermal exposures even a concern? • For occupational, once you know the exposure routes and PPE in place, you can find out what remaining tests need to be done or determine if other experiments need to be conducted. PPE though should address dermal exposure unless employees take shortcuts	• Analytical Techniques 6(#); 19(%) • Control Technologies 7(#); 23(%) • MWCNT Processing Methods 7(#); 23(%) • MWCNT Purity 5(#); 16(%) • MWCNT Synthesis Methods 5(#); 16(%) • Personal Protective Equipment 8(#); 26(%) • Other 2(#); 6(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 16(%) • Aggregation/Agglomeration State 7(#); 23(%) • Applied Coatings 7(#); 23(%) • Biodegradability 5(#); 16(%) • Catalytic Activity 2(#); 6(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 6(#); 19(%) • Matrix Bound vs. Free 8(#); 26(%) • Morphology (e.g. aspect ratio, length, width, shape) 7(#); 23(%) • Persistence 6(#); 19(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 7(#); 23(%) • Specific Surface Area 4(#); 13(%) • Structural Formula/Molecular Structure 5(#); 16(%) • Surface Chemistry 7(#); 23(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 1(#); 3(%) • Sediment 0(#); 0(%) • Soil 2(#); 6(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 3(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 6(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 2(#); 6(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 3(#); 10(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 6(#); 19(%) • Chronic Exposure 8(#); 26(%) • Exposure Route 6(#); 19(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 6(#); 19(%) • Individual Activity Level 6(#); 19(%) • Life Stage 2(#); 6(%) • Occupation 7(#); 23(%) • Subchronic Exposure 5(#); 16(%) • Susceptible Populations/Individuals 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
37	Human Consumer ngestion	20(#) 65(%)	10(#) 32(%)	1(#) 3(%)	11(#) 35(%)	3(#) 10(%)	6(#) 19(%)	2(#) 6(%)	6(#) 19(%)	12(#) 39(%)	• Most probab e exposure route through contaminanted food • ack of exper mentia data No data ava ab e on consumer contact w th MWCNT f ame retardant upho stery coatings • Rel ab e data on consumer exposure s not yet ava ab e but can estimate consumer exposures • nsuff c ent quantities Few stud es are ava ab e on th s other than compar sons to decaBDE • ngestion has not been wel stud ed n terms of MWCNT exposures R sk due to exposure s stil not known • mited exposure, metabo sm and transport not expected • The kel hood of ngestion exposure to a CNT conta n ng f re retardant s kely to be very ow and f so aga n secondary to nha ation/ derma exposure • no supportive data for r sk • Larger agg omorated structures and CNT mixed w th matr x mater a cou d be ngested hand to mouth	• Ana ytica Techn ques 8(#) 26(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 6(#) 19(%) • App ed Coatings 7(#) 23(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 4(#) 13(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 2(#) 6(%) • L poph c ty 4(#) 13(%) • Matr x Bound vs Free 6(#) 19(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 6(#) 19(%) • Redox Potentia 2(#) 6(%) • S ze/S ze D str bution 5(#) 16(%) • Spec f c Surface Area 3(#) 10(%) • Structura Formu a/Mo ecu ar Structure 5(#) 16(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 6(%) • Groundwater 2(#) 6(%) • Sed ment 0(#) 0(%) • So 1(#) 3(%) • Surface Water 2(#) 6(%) • Wastewater 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 0(#) 0(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 0(#) 0(%) • So /Sed ment Fractionation 0(#) 0(%) • Temperature 3(#) 10(%) • W nd 1(#) 3(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 2(#) 6(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 3(#) 10(%) • Natura Organ c Matter (NOM) 2(#) 6(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 16(%) • B oaccumu ation 3(#) 10(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 1(#) 3(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 16(%) • Chron c Exposure 9(#) 29(%) • Exposure Route 9(#) 29(%) • Geograph c Location (i.e. rura vs urban) 1(#) 3(%) • Hab tat Structure 2(#) 6(%) • Human Activ ty 8(#) 26(%) • nd v dua Activ ty Level 7(#) 23(%) • L fe Stage 5(#) 16(%) • Occupation 4(#) 13(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
38	Human Consumer nha ation	20(#) 65(%)	10(#) 32(%)	1(#) 3(%)	16(#) 52(%)	2(#) 6(%)	2(#) 6(%)	3(#) 10(%)	6(#) 19(%)	11(#) 35(%)	• Potentia rea ease and accumu ation n dust • Due to the ear y stage n th use of CNT conta n ng products th s nformation s comp etely ack ng yet as d scussed n Chapter 2 the potentia for release s ev dent from dusts contian ng decaBDE being elease from textiles and nsu ation mater a s • Few stud es are ava ab e on th s other than compar sons to decaBDE • Lack of exper menta data • Potentia for da y acute exposures bu d up of product n househo d dust, etc • An ma data supportive of a resp ratory d sease r sk • kely route of exposure • No data ava ab e on consumer contact w th MWCNT f ame retardant upho stery coatings • Once embedded nto a po ymer or a surface coating exposure through nha ation s expected to be min ma	• Ana ytica Techn ques 10(#) 32(%) • Contro Techno og es 7(#) 23(%) • MWCNT Process ng Methods 5(#) 16(%) • MWCNT Pur ty 7(#) 23(%) • MWCNT Synthes s Methods 5(#) 16(%) • Persona Protective Equ pment 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 23(%) • Aggregation/Agg omeration State 11(#) 35(%) • App ed Coatings 11(#) 35(%) • B odegradab ty 8(#) 26(%) • Cata ytic Activ ty 3(#) 10(%) • Charge 6(#) 19(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 29(%) • Pers stence 11(#) 35(%) • Redox Potentia 5(#) 16(%) • S ze/S ze D str bution 11(#) 35(%) • Spec f c Surface Area 7(#) 23(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 10(#) 32(%) • Groundwater 0(#) 0(%) • Sed ment 0(#) 0(%) • So 2(#) 6(%) • Surface Water 1(#) 3(%) • Wastewater 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 0(#) 0(%) • So /Sed ment Fractionation 0(#) 0(%) • Temperature 3(#) 10(%) • W nd 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 2(#) 6(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 2(#) 6(%) • Heavy Meta s n Env ronment 3(#) 10(%) • on c Strength n Env ronment 2(#) 6(%) • L gand Concentrations n Env ronment 2(#) 6(%) • Natura Organ c Matter (NOM) 2(#) 6(%) • Other Contaminants n Env ronment 4(#) 13(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 13(%) • B oaccumu ation 3(#) 10(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 1(#) 3(%) • Organ sm Hea th 3(#) 10(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 8(#) 26(%) • Chron c Exposure 11(#) 35(%) • Exposure Route 10(#) 32(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 2(#) 6(%) • Human Activ ty 10(#) 32(%) • nd v dua Activ ty Level 9(#) 29(%) • L fe Stage 9(#) 29(%) • Occupation 5(#) 16(%) • Subchron c Exposure 10(#) 32(%) • Susceptib e Popu ations/ nd v dua s 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
39	Human: Consumer-Dermal	20(#); 65(%)	10(#); 32(%)	1(#); 3(%)	5(#); 16(%)	8(#); 26(%)	7(#); 23(%)	3(#); 10(%)	5(#); 16(%)	12(#); 39(%)	• Direct contact with fabric • No data available on consumer contact with MWCNT flame retardant upholstery coatings • Constant contact with skin from upholstery could lead to potential exposure • Early stage in the use of CNT containing products, this information is lacking but the potential for release is evident from dusts containing decaBDE being released from texiles and insulation materials. Therefore the level of exposure during use is important although evidence suggests potentially a low hazard from CNT via dermal exposure as is also seen with many poorly soluble particles • Few studies are available on this other than comparisons to decaBDE • Lack of adequate data to assess • Data not comprehensive, but more protective route • Dermal exposure does not seem to be a risk. Not well studied. • Limited exposure, contained in polymer matrix • Not a likely matrix • Low likelihood for exposure in products • Little to no data • Reliable data on consumer exposure is not yet available but can estimate consumer exposures	• Analytical Techniques 5(#); 16(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 5(#); 16(%) • Applied Coatings 5(#); 16(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 6(#); 19(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 16(%) • Persistence 4(#); 13(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 5(#); 16(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 3(#); 10(%) • Surface Chemistry 5(#); 16(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 3(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 2(#); 6(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 3(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 6(#); 19(%) • Chronic Exposure 7(#); 23(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 2(#); 6(%) • Human Activity 7(#); 23(%) • Individual Activity Level 7(#); 23(%) • Life Stage 4(#); 13(%) • Occupation 2(#); 6(%) • Subchronic Exposure 6(#); 19(%) • Susceptible Populations/Individuals 6(#); 19(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
40	Human: General Population-Ingestion	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	3(#); 10(%)	4(#); 13(%)	2(#); 6(%)	1(#); 3(%)	3(#); 10(%)	5(#); 16(%)	• Most likely route of exposure • Lack of adequate data to assess • Lack of experimental data • No reliable techniques for estimating general population exposures • Depends upon how product is used, breaks down, and gets exposed to particular groups (children). Very complex but data suggests inhalation issues are the primary concerns. • Little to no data	• Analytical Techniques 3(#); 10(%) • Control Technologies 3(#); 10(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 2(#); 6(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 2(#); 6(%) • Applied Coatings 3(#); 10(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 2(#); 6(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 2(#); 6(%) • Matrix Bound vs. Free 3(#); 10(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 3(#); 10(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 2(#); 6(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 2(#); 6(%) • Water Solubility/Dispersibility 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 0(#); 0(%) • Soil 1(#); 3(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 2(#); 6(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 2(#); 6(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
41	Human: General Population-Inhalation	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	5(#); 16(%)	4(#); 13(%)	0(#); 0(%)	2(#); 6(%)	2(#); 6(%)	5(#); 16(%)	• Inhalation concerns pretty well mapped out. Once you know the product application and have addressed all the other unknowns about how MWCNT can get out of the product, this information solves the rest of the problem. • Likely route of exposure • Lack of experimental data • Lack of adequate data to assess • Little to no data • No reliable techniques for estimating general population exposures	• Analytical Techniques 4(#); 13(%) • Control Technologies 3(#); 10(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 2(#); 6(%) • Personal Protective Equipment 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 3(#); 10(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 2(#); 6(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 2(#); 6(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 4(#); 13(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 3(#); 10(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 10(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 2(#); 6(%) • Surface Water 1(#); 3(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 3(#); 10(%) • Exposure Route 3(#); 10(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 1(#); 3(%) • Human Activity 3(#); 10(%) • Individual Activity Level 3(#); 10(%) • Life Stage 3(#); 10(%) • Occupation 2(#); 6(%) • Subchronic Exposure 3(#); 10(%) • Susceptible Populations/Individuals 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
42	Human: General Population-Dermal	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	1(#); 3(%)	2(#); 6(%)	6(#); 19(%)	0(#); 0(%)	4(#); 13(%)	5(#); 16(%)	• Lack of experimental data • Not a likely route • Lack of adequate data to assess • Little absorption • Would need to determine how MWCNT gets out of the product and in what form to determine if this is an issue or not, but existing data on exposure should help guide this. • Little to no data • No reliable techniques for estimating general population exposures	• Analytical Techniques 1(#); 3(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
43	Aquatic Biota-Ingestion	8(#); 26(%)	18(#); 58(%)	5(#); 16(%)	8(#); 26(%)	0(#); 0(%)	0(#); 0(%)	1(#); 3(%)	3(#); 10(%)	4(#); 13(%)	• Most likely route of exposure • There have been a number of studies on the toxic effects of MWCNTs to water-dwelling and sediment-dwelling organisms but there are many unanswered questions • Little to no data	• Analytical Techniques 4(#); 13(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 3(#); 10(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 5(#); 16(%) • Applied Coatings 4(#); 13(%) • Biodegradability 2(#); 6(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 5(#); 16(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 4(#); 13(%) • Soil 2(#); 6(%) • Surface Water 5(#); 16(%) • Wastewater 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 4(#); 13(%) • Light Availability 1(#); 3(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 4(#); 13(%) • Temperature 2(#); 6(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 2(#); 6(%) • Ionic Strength in Environment 3(#); 10(%) • Ligand Concentrations in Environment 4(#); 13(%) • Natural Organic Matter (NOM) 5(#); 16(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 5(#); 16(%) • Salinity 4(#); 13(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 16(%) • Bioaccumulation 5(#); 16(%) • Biomagnification 5(#); 16(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 13(%) • Chronic Exposure 6(#); 19(%) • Exposure Route 6(#); 19(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 2(#); 6(%) • Human Activity 2(#); 6(%) • Individual Activity Level 3(#); 10(%) • Life Stage 5(#); 16(%) • Occupation 1(#); 3(%) • Subchronic Exposure 5(#); 16(%) • Susceptible Populations/Individuals 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
44	Aquatic Biota-Inhalation	8(#); 26(%)	18(#); 58(%)	5(#); 16(%)	0(#); 0(%)	1(#); 3(%)	7(#); 23(%)	2(#); 6(%)	1(#); 3(%)	5(#); 16(%)	• Inhalation as an exposure route does not make sense for aquatic organisms • Not air breathers • Little to no data	• Analytical Techniques 1(#); 3(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
45	Aquatic Biota-Direct Contact	8(#); 26(%)	18(#); 58(%)	5(#); 16(%)	4(#); 13(%)	4(#); 13(%)	0(#); 0(%)	1(#); 3(%)	3(#); 10(%)	4(#); 13(%)	• Little likelihood of uptake across skin/carapice; only important for biofilms • Few studies have tested dermal effects with aquatic organisms • Little to no data	• Analytical Techniques 3(#); 10(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 3(#); 10(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 3(#); 10(%) • Biodegradability 1(#); 3(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 3(#); 10(%) • Matrix Bound vs. Free 3(#); 10(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 3(#); 10(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 6(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 3(#); 10(%) • Soil 1(#); 3(%) • Surface Water 4(#); 13(%) • Wastewater 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 1(#); 3(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 1(#); 3(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 3(#); 10(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 3(#); 10(%) • pH 3(#); 10(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 3(#); 10(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 10(%) • Chronic Exposure 5(#); 16(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 2(#); 6(%) • Individual Activity Level 3(#); 10(%) • Life Stage 4(#); 13(%) • Occupation 1(#); 3(%) • Subchronic Exposure 4(#); 13(%) • Susceptible Populations/Individuals 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
46	Terrestrial Biota-Ingestion	3(#); 10(%)	22(#); 71(%)	6(#); 19(%)	3(#); 10(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 6(%)	1(#); 3(%)	• There have only been a few studies on MWCNTs with earthworms	• Analytical Techniques 2(#); 6(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 2(#); 6(%) • Applied Coatings 1(#); 3(%) • Biodegradability 1(#); 3(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 3(%) • Matrix Bound vs. Free 2(#); 6(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 3(%) • Persistence 2(#); 6(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 3(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 2(#); 6(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 3(%) • Sediment 2(#); 6(%) • Soil 1(#); 3(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 1(#); 3(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 3(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 3(%) • Life Stage 1(#); 3(%) • Occupation 0(#); 0(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
47	Terrestrial Biota-Inhalation	3(#); 10(%)	22(#); 71(%)	6(#); 19(%)	1(#); 3(%)	0(#); 0(%)	2(#); 6(%)	2(#); 6(%)	0(#); 0(%)	1(#); 3(%)	• Inhalation as an exposure route does not make sense for terrestrial organisms	• Analytical Techniques 1(#); 3(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 3(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 3(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 1(#); 3(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 3(%) • Life Stage 1(#); 3(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 3(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
48	Terrestrial Biota-Direct Contact	3(#); 10(%)	22(#); 71(%)	6(#); 19(%)	1(#); 3(%)	1(#); 3(%)	1(#); 3(%)	1(#); 3(%)	1(#); 3(%)	1(#); 3(%)	• Few studies have tested dermal effects with terrestrial organisms but this is likely less important than ingestion of soils. Plant exposure to routes will be described using "direct contact" although this may not be the clearest term.	• Analytical Techniques 1(#); 3(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 1(#); 3(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 3(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 3(%) • Soil 0(#); 0(%) • Surface Water 1(#); 3(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 1(#); 3(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 3(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 3(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
49	Abiotic-Direct Contact	1(#); 3(%)	8(#); 26(%)	22(#); 71(%)	1(#); 3(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 3(%)	0(#); 0(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
50	Human Absorption	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	24(#) 77(%)	3(#) 10(%)	2(#) 6(%)	3(#) 10(%)	7(#) 23(%)	19(#) 61(%)	• Need to quantify absorption to determine f exposure occurs • ADME s v ta to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Cha enges exist n dentify ng and character z ng CNT n v vo espec a y n terms measur ng uptake, d str bution and c earance rates through the body The nature of absorption and penetration of CNT nto the body espec a y the effect of s ze, shape, etc has on regiona depos tion n the ung s mportant and ack ng • Currently very mited or no data Lack of data Section 4 2 6 • Few data ava ab e, so util ty s questionab e • No data ava ab e on MWCNT dos ng n humans • No rel ab e stud es • Not enough known concentration n ungs • Not much data adsorption n ungs s key • Stud es not yet done • Some rodent data exists • The c ose contact of the product w th peop e • Pub shed data nd cate that MWCNT are red str buted n the ungs as agg omerates and as free structures • Data does not yet exst and most known CNT effects do not depend on these elements • Some qua tative data s ava ab e for MWCNTs after nha ation stud es but tt e nformation s ava ab e for derma or ora ngestion stud es • No data but cannot rea y study n humans can t rea y study MWCNTs n textiles un ess t can be found n the b ood or ur ne and that ooks un kely need nv tro tests such as derma penetration of the powder to understand worst case f t s absorbed and f so where t goes • Some data ava ab e	• Ana ytica Techn ques 16(#) 52(%) • Contro Techno og es 7(#) 23(%) • MWCNT Process ng Methods 8(#) 26(%) • MWCNT Pur ty 10(#) 32(%) • MWCNT Synthes s Methods 7(#) 23(%) • Persona Protective Equ pment 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 14(#) 45(%) • Aggregation/Agg omeration State 15(#) 48(%) • App ed Coatings 13(#) 42(%) • B odegradab ty 10(#) 32(%) • Cata ytic Activ ty 7(#) 23(%) • Charge 12(#) 39(%) • Conductive or Magnetic Properties 6(#) 19(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 15(#) 48(%) • Matr x Bound vs Free 15(#) 48(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 18(#) 58(%) • Pers stence 13(#) 42(%) • Redox Potentia 7(#) 23(%) • S ze/S ze D str bution 15(#) 48(%) • Spec f c Surface Area 13(#) 42(%) • Structura Formu a/Mo ecu ar Structure 10(#) 32(%) • Surface Chem stry 14(#) 45(%) • Water So ub ty/D spers b ty 16(#) 52(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 29(%) • Groundwater 3(#) 10(%) • Sed ment 2(#) 6(%) • So 4(#) 13(%) • Surface Water 6(#) 19(%) • Wastewater 4(#) 13(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 6(#) 19(%) • W nd 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 10(#) 32(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 7(#) 23(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 7(#) 23(%) • Other Contaminants n Env ronment 6(#) 19(%) • pH 9(#) 29(%) • Protein Concentration n Env ronment 11(#) 35(%) • Sa n ty 8(#) 26(%) • Surfactant (in Lab) 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 14(#) 45(%) • B oaccumu ation 13(#) 42(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 8(#) 26(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 8(#) 26(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 13(#) 42(%) • Chron c Exposure 14(#) 45(%) • Exposure Route 15(#) 48(%) • Geograph c Location (i.e. rura vs urban) 5(#) 16(%) • Hab tat Structure 4(#) 13(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 8(#) 26(%) • Occupation 9(#) 29(%) • Subchron c Exposure 13(#) 42(%) • Susceptib e Popu ations/ nd v dua s 12(#) 39(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
51	Human D str bution	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	22(#) 71(%)	7(#) 23(%)	0(#) 0(%)	3(#) 10(%)	7(#) 23(%)	19(#) 61(%)	• ADME s v ta n order to understand the toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Cha enges exist n dentify ng and character s ng CNT n v vo espec a y n terms measur ng uptake, d str bution and c earance rates through the body a though stud es are beginn ng to conf rm the ab ty of CNT from the ung to the p eura (a though the Mercer 2010 study wh h best shows th s s not mentioned n the document) • No data ava ab e on MWCNT dos ng n humans • No rel ab e stud es • Not much data oca zed accumu ation cou d be a prob em • Stud es not yet done • Pub shed data nd cate that MWCNT are red str buted n the ung as agg omerates and as free structures • Some data ava ab e • Some rodent data exists • f absorption occurs th s s cr tica • May undergo transport, espec a y functiona zed mater a not enough known • Not much ev dence on f d str bution throughout the body occurs • CNT have been shown to move and accumu ate n organs • Few stud es show d str bution throughout organ sms after nha ation or ora exposure. Most MWCNTs rema n near where they entered the organ sm or are excreted
52	Human Metabo sm	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	15(#) 48(%)	8(#) 26(%)	6(#) 19(%)	2(#) 6(%)	6(#) 19(%)	21(#) 68(%)	• ADME s v ta n order to understand the toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Currently very mited or no data Lack of data Section 4 2 6 • No data ava ab e on MWCNT dos ng n humans • No rel ab e stud es • Remova from ungs s unknown • Stud es not yet done • t s un kely that substantia MWCNT metabo sm w occur • CNTs may not be metabo zed • Data says most MWCNTs are el minated after ngestion • Doesn t need to be metabo zed • f absorption occurs th s s cr tica • The chem ca nature of CNT and observed b opers stence means that metabo sm s un k y to resu t n mod f cation of the CNT or production of toxic metabo tes etc a though the metabo sm of contaminating substances formed dur ng production etc may be of nterest • There are few data on metabo sm, but what are ava ab e show that CNTs can be functiona zed to carboxy c ac ds wh ch may fac tate excretion Other than that pathway tt e mpact s expected • Data needed on mechan sm of toxic ty (lung) • Data does not yet exist and most known CNT effects do not depend on these elements
53	Human Excretion	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	20(#) 65(%)	8(#) 26(%)	1(#) 3(%)	3(#) 10(%)	6(#) 19(%)	20(#) 65(%)	• There are data to show that CNTs can be el minated a beit a s ow process depend ng on the f ber ength • ADME s v ta n order to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to asess ADME of MWCNTs • Cha enges exist n dentify ng and character s ng CNT n v vo n terms c earance rates through the body and routes of excretion based on d ffer ng routes of exposure. Some stud es do exist show ng ur nary excretion of SWCNT after ntravenous n ection but such stud es are of ow relevance to the use of CNT and subsquent exposure routes as descr bed n th s CEA • Currently very mited or no data Lack of data Section 4 2 6 • L tt e data s ava ab e on th s but some ong time pers stence has been observed after ung exposures • No data ava ab e on MWCNT dos ng n humans • No rel ab e stud es • Stud es not yet done • Not expected to be absorbed n gut • f absorption occurs th s s cr tica • An ma stud es show excretion • Relatively c ear modes of excretion • L tt e to no data • Data does not yet exist and most known CNT effects do not depend on these elements

ID	Element-RRF Pair	Influential Factors						
		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
51	Human D str bution	• Ana ytica Techn ques 15(#) 48(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 8(#) 26(%) • MWCNT Pur ty 10(#) 32(%) • MWCNT Synthes s Methods 7(#) 23(%) • Persona Protective Equ pment 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 39(%) • Aggregation/Agg omeration State 14(#) 45(%) • App ed Coatings 13(#) 42(%) • B odegradab ty 13(#) 42(%) • Cata ytic Activ ty 8(#) 26(%) • Charge 11(#) 35(%) • Conductive or Magnetic Properties 5(#) 16(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 15(#) 48(%) • Matr x Bound vs Free 13(#) 42(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 16(#) 52(%) • Pers stence 13(#) 42(%) • Redox Potentia 8(#) 26(%) • S ze/S ze D str bution 14(#) 45(%) • Spec f c Surface Area 12(#) 39(%) • Structura Formu a/Mo ecu ar Structure 10(#) 32(%) • Surface Chem stry 14(#) 45(%) • Water So ub ty/D spers b ty 16(#) 52(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 3(#) 10(%) • Sed ment 2(#) 6(%) • So 3(#) 10(%) • Surface Water 4(#) 13(%) • Wastewater 4(#) 13(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 5(#) 16(%) • W nd 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 10(#) 32(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 7(#) 23(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 8(#) 26(%) • Protein Concentration n Env ronment 10(#) 32(%) • Sa n ty 6(#) 19(%) • Surfactant (in Lab) 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 12(#) 39(%) • B oaccumu ation 12(#) 39(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 9(#) 29(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 23(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 12(#) 39(%) • Chron c Exposure 12(#) 39(%) • Exposure Route 13(#) 42(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 7(#) 23(%) • nd v dua Activ ty Level 8(#) 26(%) • L fe Stage 8(#) 26(%) • Occupation 6(#) 19(%) • Subchron c Exposure 11(#) 35(%) • Susceptib e Popu ations/ nd v dua s 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
52	Human Metabo sm	• Ana ytica Techn ques 13(#) 42(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 7(#) 23(%) • MWCNT Pur ty 10(#) 32(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 32(%) • Aggregation/Agg omeration State 10(#) 32(%) • App ed Coatings 11(#) 35(%) • B odegradab ty 11(#) 35(%) • Cata ytic Activ ty 6(#) 19(%) • Charge 8(#) 26(%) • Conductive or Magnetic Properties 5(#) 16(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 12(#) 39(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 13(#) 42(%) • Pers stence 11(#) 35(%) • Redox Potentia 7(#) 23(%) • S ze/S ze D str bution 10(#) 32(%) • Spec f c Surface Area 9(#) 29(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 11(#) 35(%) • Water So ub ty/D spers b ty 14(#) 45(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 3(#) 10(%) • Sed ment 2(#) 6(%) • So 3(#) 10(%) • Surface Water 3(#) 10(%) • Wastewater 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 5(#) 16(%) • W nd 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 8(#) 26(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 7(#) 23(%) • on c Strength n Env ronment 5(#) 16(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 6(#) 19(%) • Other Contaminants n Env ronment 7(#) 23(%) • pH 8(#) 26(%) • Protein Concentration n Env ronment 9(#) 29(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 11(#) 35(%) • B oaccumu ation 10(#) 32(%) • B omagn f cation 6(#) 19(%) • M crob a Commun ties n Env ronment 5(#) 16(%) • Organ sm Hea th 8(#) 26(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 19(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 10(#) 32(%) • Chron c Exposure 10(#) 32(%) • Exposure Route 10(#) 32(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 6(#) 19(%) • nd v dua Activ ty Level 7(#) 23(%) • L fe Stage 8(#) 26(%) • Occupation 5(#) 16(%) • Subchron c Exposure 10(#) 32(%) • Susceptib e Popu ations/ nd v dua s 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
53	Human Excretion	• Ana ytica Techn ques 15(#) 48(%) • Contro Techno og es 4(#) 13(%) • MWCNT Process ng Methods 8(#) 26(%) • MWCNT Pur ty 9(#) 29(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 29(%) • Aggregation/Agg omeration State 12(#) 39(%) • App ed Coatings 11(#) 35(%) • B odegradab ty 12(#) 39(%) • Cata ytic Activ ty 7(#) 23(%) • Charge 10(#) 32(%) • Conductive or Magnetic Properties 5(#) 16(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 14(#) 45(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 16(#) 52(%) • Pers stence 14(#) 45(%) • Redox Potentia 8(#) 26(%) • S ze/S ze D str bution 14(#) 45(%) • Spec f c Surface Area 11(#) 35(%) • Structura Formu a/Mo ecu ar Structure 9(#) 29(%) • Surface Chem stry 16(#) 52(%) • Water So ub ty/D spers b ty 16(#) 52(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 5(#) 16(%) • Sed ment 2(#) 6(%) • So 3(#) 10(%) • Surface Water 4(#) 13(%) • Wastewater 4(#) 13(%) • Other 2(#) 6(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 5(#) 16(%) • W nd 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 13(%) • D spers ng Agents 9(#) 29(%) • D sso ved Oxygen Content 3(#) 10(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 9(#) 29(%) • Protein Concentration n Env ronment 10(#) 32(%) • Sa n ty 7(#) 23(%) • Surfactant (in Lab) 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 14(#) 45(%) • B oaccumu ation 12(#) 39(%) • B omagn f cation 6(#) 19(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 10(#) 32(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 23(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 10(#) 32(%) • Chron c Exposure 11(#) 35(%) • Exposure Route 12(#) 39(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 6(#) 19(%) • nd v dua Activ ty Level 7(#) 23(%) • L fe Stage 8(#) 26(%) • Occupation 6(#) 19(%) • Subchron c Exposure 10(#) 32(%) • Susceptib e Popu ations/ nd v dua s 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
54	Aquatic B ota Absorption	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	12(#) 39(%)	2(#) 6(%)	1(#) 3(%)	2(#) 6(%)	6(#) 19(%)	7(#) 23(%)	• Need to quantify absorption to determine f exposure occurs • Currently very mited or no data • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ronments n order to character se uptake, d str butions or remova from ecosystems n add tion there are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t wh ch therefore may mpact on the ab ty of measur ng excretion rates • Stud es not yet done • Data s over y emp r ca • Some data ava ab e for sma b ota and poss b y f sh • Many stud es have shown a ack of absorption of MWCNTs nto tissues • L mited data	• Ana ytica Techn ques 7(#) 23(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 4(#) 13(%) • MWCNT Pur ty 6(#) 19(%) • MWCNT Synthes s Methods 4(#) 13(%) • Persona Protective Equ pment 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 26(%) • Aggregation/Agg omeration State 9(#) 29(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 6(#) 19(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 5(#) 16(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 9(#) 29(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 29(%) • Pers stence 7(#) 23(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 9(#) 29(%) • Spec f c Surface Area 7(#) 23(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 10(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 10(%) • Groundwater 5(#) 16(%) • Sed ment 5(#) 16(%) • So 4(#) 13(%) • Surface Water 7(#) 23(%) • Wastewater 5(#) 16(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 13(%) • L ght Ava ab ty 2(#) 6(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 5(#) 16(%) • W nd 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 6(#) 19(%) • D sso ved Oxygen Content 5(#) 16(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 6(#) 19(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 8(#) 26(%) • Other Contaminants n Env ronment 4(#) 13(%) • pH 6(#) 19(%) • Protein Concentration n Env ronment 7(#) 23(%) • Sa n ty 6(#) 19(%) • Surfactant (in Lab) 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 23(%) • B oaccumu ation 6(#) 19(%) • B omagn f cation 5(#) 16(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 7(#) 23(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 23(%) • Chron c Exposure 7(#) 23(%) • Exposure Route 6(#) 19(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 4(#) 13(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 4(#) 13(%) • Occupation 1(#) 3(%) • Subchron c Exposure 5(#) 16(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
55	Aquatic B ota D str bution	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	12(#) 39(%)	1(#) 3(%)	2(#) 6(%)	2(#) 6(%)	3(#) 10(%)	10(#) 32(%)	• Currently very mited data • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ronments n order to character ze uptake, d str butions d str butions or remova from ecosystems • Stud es not yet done • Many stud es have shown a ack of absorption of MWCNTs nto tissues • t seems un kely that d str bution w th n aquatic b ota w have an mpact on b oconcentration or effects • f absorption occurs th s s cr tica • L mited data • Data s over y emp r ca	• Ana ytica Techn ques 6(#) 19(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 4(#) 13(%) • MWCNT Pur ty 5(#) 16(%) • MWCNT Synthes s Methods 4(#) 13(%) • Persona Protective Equ pment 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 23(%) • Aggregation/Agg omeration State 9(#) 29(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 7(#) 23(%) • Cata ytic Activ ty 5(#) 16(%) • Charge 6(#) 19(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 8(#) 26(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 29(%) • Pers stence 7(#) 23(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 8(#) 26(%) • Spec f c Surface Area 7(#) 23(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 9(#) 29(%) • Water So ub ty/D spers b ty 10(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 10(%) • Groundwater 5(#) 16(%) • Sed ment 5(#) 16(%) • So 5(#) 16(%) • Surface Water 7(#) 23(%) • Wastewater 6(#) 19(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 10(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 3(#) 10(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 5(#) 16(%) • W nd 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 4(#) 13(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 4(#) 13(%) • Natura Organ c Matter (NOM) 7(#) 23(%) • Other Contaminants n Env ronment 5(#) 16(%) • pH 5(#) 16(%) • Protein Concentration n Env ronment 6(#) 19(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 8(#) 26(%) • B oaccumu ation 8(#) 26(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 9(#) 29(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 19(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 23(%) • Chron c Exposure 7(#) 23(%) • Exposure Route 6(#) 19(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 5(#) 16(%) • Occupation 2(#) 6(%) • Subchron c Exposure 6(#) 19(%) • Susceptib e Popu ations/ nd v dua s 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
56	Aquatic B ota Metabo sm	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	7(#) 23(%)	2(#) 6(%)	6(#) 19(%)	1(#) 3(%)	3(#) 10(%)	11(#) 35(%)	• Currently very mited data • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ronments n order to character ze uptake, d str butions d str butions or remova from ecosystems • Stud es not yet done • t seems un kely that metabo sm w th n aquatic b ota w have an mpact on b oconcentration or effects • MWCNTs are expected to be fa r y res stant to metabo sm • f absorption occurs th s s cr tica • L mited data • Data s over y emp r ca	• Ana ytica Techn ques 4(#) 13(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 3(#) 10(%) • Aggregation/Agg omeration State 4(#) 13(%) • App ed Coatings 4(#) 13(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 3(#) 10(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 3(#) 10(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 5(#) 16(%) • Matr x Bound vs Free 5(#) 16(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 5(#) 16(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 4(#) 13(%) • Spec f c Surface Area 4(#) 13(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 10(%) • Groundwater 3(#) 10(%) • Sed ment 3(#) 10(%) • So 3(#) 10(%) • Surface Water 5(#) 16(%) • Wastewater 4(#) 13(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 4(#) 13(%) • W nd 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 5(#) 16(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 3(#) 10(%) • L gand Concentrations n Env ronment 3(#) 10(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 3(#) 10(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 16(%) • B oaccumu ation 4(#) 13(%) • B omagn f cation 4(#) 13(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 5(#) 16(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 10(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 13(%) • Chron c Exposure 4(#) 13(%) • Exposure Route 3(#) 10(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 4(#) 13(%) • Occupation 1(#) 3(%) • Subchron c Exposure 4(#) 13(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
57	Aquatic B ota Excretion	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	10(#) 32(%)	3(#) 10(%)	2(#) 6(%)	1(#) 3(%)	4(#) 13(%)	10(#) 32(%)	• Currently very mited or no data • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ornements n order to character se uptake, d str butions or remova from ecosystems n add tion there are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t wh ch therefore may mpact on the ab ty of measur ng excretion rates • D fferent stud es have shown d fferent extents to wh ch organ sms can excrete MWCNTs accumu ated n the gut tract • f absorption occurs th s s cr tica • L mited data • Data s over y emp r ca
58	Terrestrial Biota-Absorption	8(#); 26(%)	17(#); 55(%)	6(#); 19(%)	7(#); 23(%)	0(#); 0(%)	1(#); 3(%)	3(#); 10(%)	1(#); 3(%)	4(#); 13(%)	• Need to quantify absorption to determine if exposure occurs • Seems that some data is out there already on rat studies • Currently very limited or no data • Similar challenges as for human studies in terms of monitoring and distinguishing particles in complex environments in order to characterize uptake, distributions or removal from ecosystems • Several studies have shown a lack of absorption of MWCNTs into tissues • If absorption occurs, this is critical
59	Terrestrial Biota-Distribution	8(#); 26(%)	17(#); 55(%)	6(#); 19(%)	6(#); 19(%)	1(#); 3(%)	1(#); 3(%)	3(#); 10(%)	1(#); 3(%)	4(#); 13(%)	• Seems that some data is out there already on Rat studies • Currently very limited or no data • Similar challenges as for human studies in terms of monitoring and distinguishing particles in complex environments in order to characterize uptake, distributions or removal from ecosystems • Several studies have shown a lack of absorption of MWCNTs into tissues • If absorption occurs, this is critical

ID	Element-RRF Pair	Influential Factors						
		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
57	Aquatic B ota Excretion	• Ana ytica Techn ques 6(#) 19(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 3(#) 10(%) • MWCNT Pur ty 4(#) 13(%) • MWCNT Synthes s Methods 2(#) 6(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 7(#) 23(%) • App ed Coatings 6(#) 19(%) • B odegradab ty 7(#) 23(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 5(#) 16(%) • Conductive or Magnetic Properties 3(#) 10(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 6(#) 19(%) • Matr x Bound vs Free 6(#) 19(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 26(%) • Pers stence 7(#) 23(%) • Redox Potentia 3(#) 10(%) • S ze/S ze D str bution 6(#) 19(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 5(#) 16(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 10(%) • Groundwater 3(#) 10(%) • Sed ment 4(#) 13(%) • So 3(#) 10(%) • Surface Water 6(#) 19(%) • Wastewater 4(#) 13(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 2(#) 6(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 4(#) 13(%) • W nd 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 10(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 3(#) 10(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 3(#) 10(%) • Natura Organ c Matter (NOM) 4(#) 13(%) • Other Contaminants n Env ronment 3(#) 10(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 3(#) 10(%) • Surfactant (in Lab) 3(#) 10(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 23(%) • B oaccumu ation 7(#) 23(%) • B omagn f cation 6(#) 19(%) • M crob a Commun ties n Env ronment 4(#) 13(%) • Organ sm Hea th 7(#) 23(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 19(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 16(%) • Chron c Exposure 5(#) 16(%) • Exposure Route 4(#) 13(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 3(#) 10(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 5(#) 16(%) • Occupation 2(#) 6(%) • Subchron c Exposure 5(#) 16(%) • Susceptib e Popu ations/ nd v dua s 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
58	Terrestrial Biota-Absorption	• Analytical Techniques 3(#); 10(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 10(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 2(#); 6(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 1(#); 3(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 3(#); 10(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 10(%) • Groundwater 2(#); 6(%) • Sediment 1(#); 3(%) • Soil 3(#); 10(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 2(#); 6(%) • Human Activity 1(#); 3(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 1(#); 3(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
59	Terrestrial Biota-Distribution	• Analytical Techniques 3(#); 10(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 10(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 2(#); 6(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 1(#); 3(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 2(#); 6(%) • Sediment 1(#); 3(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 1(#); 3(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
60	Terrestrial Biota-Metabolism	8(#); 26(%)	17(#); 55(%)	6(#); 19(%)	4(#); 13(%)	2(#); 6(%)	2(#); 6(%)	2(#); 6(%)	2(#); 6(%)	4(#); 13(%)	• Seems that some data is out there already on Rat studies • Currently very limited or no data • MWCNTs are expected to be fairly resistant to metabolism • The chemical nature of CNT and observed biopersistence means that metabolism is unlikly to result in modification of the CNT or production of toxic metabolites etc although the metabolism of contaminating substances formed during production etc may be of interest • If absorption occurs, this is critical	• Analytical Techniques 2(#); 6(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 2(#); 6(%) • Applied Coatings 2(#); 6(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 1(#); 3(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 3(#); 10(%) • Matrix Bound vs. Free 3(#); 10(%) • Morphology (e.g. aspect ratio, length, width, shape) 3(#); 10(%) • Persistence 3(#); 10(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 3(#); 10(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 2(#); 6(%) • Sediment 1(#); 3(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 3(#); 10(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 1(#); 3(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
61	Terrestrial Biota-Excretion	8(#); 26(%)	17(#); 55(%)	6(#); 19(%)	5(#); 16(%)	3(#); 10(%)	0(#); 0(%)	2(#); 6(%)	1(#); 3(%)	5(#); 16(%)	• Seems that some data is out there already on Rat studies • Currently very limited or no data • Similar challenges as for human studies in terms of monitoring and distinguishing particles in complex environments in order to characterize uptake, distributions or removal from ecosystems • If absorption occurs, this is critical • A few studies have shown elimination of MWCNTs by organisms	• Analytical Techniques 3(#); 10(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 2(#); 6(%) • Biodegradability 3(#); 10(%) • Catalytic Activity 1(#); 3(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 4(#); 13(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 2(#); 6(%) • Sediment 1(#); 3(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 1(#); 3(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 2(#); 6(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 1(#); 3(%) • Ligand Concentrations in Environment 1(#); 3(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 1(#); 3(%) • pH 1(#); 3(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 6(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 2(#); 6(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 4(#); 13(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 6(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 2(#); 6(%) • Life Stage 2(#); 6(%) • Occupation 1(#); 3(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
62	Abiotic-Absorption	3(#); 10(%)	13(#); 42(%)	15(#); 48(%)	3(#); 10(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	3(#); 10(%)	• Currently very limited or no data	• Analytical Techniques 1(#); 3(%) • Control Technologies 2(#); 6(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 2(#); 6(%) • Personal Protective Equipment 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 2(#); 6(%) • Applied Coatings 2(#); 6(%) • Biodegradability 2(#); 6(%) • Catalytic Activity 2(#); 6(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 2(#); 6(%) • Matrix Bound vs. Free 2(#); 6(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 2(#); 6(%) • Redox Potential 2(#); 6(%) • Size/Size Distribution 2(#); 6(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 2(#); 6(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 1(#); 3(%) • Sediment 1(#); 3(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 2(#); 6(%) • Other 2(#); 6(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 2(#); 6(%) • Wind 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 2(#); 6(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 2(#); 6(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 2(#); 6(%) • Other Contaminants in Environment 2(#); 6(%) • pH 2(#); 6(%) • Protein Concentration in Environment 2(#); 6(%) • Salinity 2(#); 6(%) • Surfactant (in Lab) 2(#); 6(%) • Other 1(#); 3(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 1(#); 3(%) • Biomagnification 1(#); 3(%) • Microbial Communities in Environment 2(#); 6(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 1(#); 3(%) • Geographic Location (i.e. rural vs. urban) 1(#); 3(%) • Habitat Structure 1(#); 3(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 3(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 3(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
63	Human Cancer	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	23(#) 74(%)	6(#) 19(%)	0(#) 0(%)	8(#) 26(%)	5(#) 16(%)	16(#) 52(%)	• Ev dence of DNA change • Existing data suggesting s mi ar ties between MWCNT and asbestos • th nk there s enough ev dent to state that some MWCNTs might cause cancer under some c rcumstances • Defin tive stud es have not been done • ncomp ete data ava ab e ana ogy to asbestos but no d rect data for MWCNT • Known d srupter of mitos s but tt e to no chron c exposure data to nd cate poss b e cancers • No data Tab e 5 1 • Potentia for asbestos ke effects • The carc nogen c endpo nt has yet to be conv nc ng y estab shed for CNT or has the ong term effects of exposure acute or chron c a though severa stud es have now nc uded onger post exposure per ods of ~6months 1yr Stud es have typ ca y focused on the use of genetica y susceptab e an ma s or have emp oyed nappropr ate assays to conv nc ng y estab sh f CNT are or are not carc nogen c or genotoxic (e.g use of the Ames test or use of short compact f bres n an ntraper tonea assay) • Some ev dence has been reported of effects from nha ation and d rect mp anting the stiffness of the MWCNT depends on the process • An ma P stud es nd cate a poss b e cancer r sk • Data are a ready ava ab e to suggest ong term effects depend ng on the s ze and f ber ength • There s some ava ab e data but more wou d be helpfu • nha ation stud es are not d rectly ava ab e for th s • No chron c stud es • L mited data • Want to be sure to prevent worker nha ation exposure and determine f there are ong term effects from exposure	• Ana ytica Techn ques 9(#) 29(%) • Contro Techno og es 8(#) 26(%) • MWCNT Process ng Methods 6(#) 19(%) • MWCNT Pur ty 8(#) 26(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 29(%) • Aggregation/Agg omeration State 14(#) 45(%) • App ed Coatings 11(#) 35(%) • B odegradab ty 10(#) 32(%) • Cata ytic Activ ty 8(#) 26(%) • Charge 8(#) 26(%) • Conductive or Magnetic Properties 3(#) 10(%) • Crysta ne Phase 5(#) 16(%) • L poph c ty 10(#) 32(%) • Matr x Bound vs Free 13(#) 42(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 13(#) 42(%) • Pers stence 13(#) 42(%) • Redox Potentia 10(#) 32(%) • S ze/S ze D str bution 13(#) 42(%) • Spec f c Surface Area 11(#) 35(%) • Structura Formu a/Mo ecu ar Structure 6(#) 19(%) • Surface Chem stry 13(#) 42(%) • Water So ub ty/D spers b ty 9(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 3(#) 10(%) • Sed ment 1(#) 3(%) • So 3(#) 10(%) • Surface Water 4(#) 13(%) • Wastewater 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 1(#) 3(%) • Temperature 2(#) 6(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 6(#) 19(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 5(#) 16(%) • Natura Organ c Matter (NOM) 4(#) 13(%) • Other Contaminants n Env ronment 7(#) 23(%) • pH 3(#) 10(%) • Protein Concentration n Env ronment 4(#) 13(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 10(#) 32(%) • B oaccumu ation 9(#) 29(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 8(#) 26(%) • Spec es/ nd v dua Developmenta Behav or 5(#) 16(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 12(#) 39(%) • Chron c Exposure 18(#) 58(%) • Exposure Route 17(#) 55(%) • Geograph c Location (i.e. rura vs urban) 5(#) 16(%) • Hab tat Structure 5(#) 16(%) • Human Activ ty 10(#) 32(%) • nd v dua Activ ty Level 11(#) 35(%) • L fe Stage 10(#) 32(%) • Occupation 14(#) 45(%) • Subchron c Exposure 15(#) 48(%) • Susceptib e Popu ations/ nd v dua s 17(#) 55(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
64	Human Non cancer	29(#) 94(%)	2(#) 6(%)	0(#) 0(%)	21(#) 68(%)	7(#) 23(%)	1(#) 3(%)	6(#) 19(%)	9(#) 29(%)	14(#) 45(%)	• Abundant ev dence for f bros s • An ma nha ation/asp ration/ T stud es nd cate ung f bros s • Data are a ready ava ab e to suggest ong term effects depend ng on the s ze and f ber ength • Data documenting nf ammatory response n resp ratory system • Defin tive stud es have not been done • nsuff c ent data • No data Tab e 5 1 • Fa r y good grasp on f bros s and potentia for mesothel oma from nha ation but not much data on derma exposures • No chron c stud es • Non cancerous endpo nts such as nf ammation (lung ocu ar or derma), f bros s and granu oma formation have most typ ca y been descr bed n numerous stud es nc ud ng severa h gh y robust stud es us ng nha ation expsoure a though the functiona mpact of these observations (i.e. n terms of c n ca d sease) s stil ack ng There has ben some nvestigation of the ro e of contaminants (e.g meta s) n the el c ta on of nf ammation (inha ation and derma exposure) as wel as the ro e of shape. There s mited nformation on the systemic toxic ty of CNT a though some stud es do show potentia card ovascu ar as wel as mmuno og ca effects • Some h nt of asbestos ke responses • Affect organ function • Th s cou d be mportant but we s mp y do not know at th s po nt n time • Stud es on a range of endpo nts are ava ab e n the terature wh ch show mixed resu ts • L mited data • Want to be sure to prevent worker nha ation exposure and determine f there are ong term effects from exposure	• Ana ytica Techn ques 8(#) 26(%) • Contro Techno og es 8(#) 26(%) • MWCNT Process ng Methods 6(#) 19(%) • MWCNT Pur ty 8(#) 26(%) • MWCNT Synthes s Methods 6(#) 19(%) • Persona Protective Equ pment 9(#) 29(%) • Other 1(#) 3(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 32(%) • Aggregation/Agg omeration State 13(#) 42(%) • App ed Coatings 11(#) 35(%) • B odegradab ty 10(#) 32(%) • Cata ytic Activ ty 9(#) 29(%) • Charge 9(#) 29(%) • Conductive or Magnetic Properties 4(#) 13(%) • Crysta ne Phase 4(#) 13(%) • L poph c ty 10(#) 32(%) • Matr x Bound vs Free 12(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 13(#) 42(%) • Pers stence 11(#) 35(%) • Redox Potentia 8(#) 26(%) • S ze/S ze D str bution 13(#) 42(%) • Spec f c Surface Area 10(#) 32(%) • Structura Formu a/Mo ecu ar Structure 7(#) 23(%) • Surface Chem stry 12(#) 39(%) • Water So ub ty/D spers b ty 10(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 23(%) • Groundwater 5(#) 16(%) • Sed ment 1(#) 3(%) • So 3(#) 10(%) • Surface Water 5(#) 16(%) • Wastewater 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 1(#) 3(%) • Temperature 2(#) 6(%) • W nd 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 6(%) • D spers ng Agents 6(#) 19(%) • D sso ved Oxygen Content 1(#) 3(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 7(#) 23(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 5(#) 16(%) • Other Contaminants n Env ronment 7(#) 23(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 23(%) • B oaccumu ation 9(#) 29(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 3(#) 10(%) • Organ sm Hea th 8(#) 26(%) • Spec es/ nd v dua Developmenta Behav or 6(#) 19(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 23(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 11(#) 35(%) • Chron c Exposure 16(#) 52(%) • Exposure Route 16(#) 52(%) • Geograph c Location (i.e. rura vs urban) 4(#) 13(%) • Hab tat Structure 5(#) 16(%) • Human Activ ty 9(#) 29(%) • nd v dua Activ ty Level 11(#) 35(%) • L fe Stage 11(#) 35(%) • Occupation 14(#) 45(%) • Subchron c Exposure 14(#) 45(%) • Susceptib e Popu ations/ nd v dua s 14(#) 45(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
65	Human-Reproductive/ Developmental	29(#); 94(%)	2(#); 6(%)	0(#); 0(%)	10(#); 32(%)	15(#); 48(%)	4(#); 13(%)	3(#); 10(%)	5(#); 16(%)	21(#); 68(%)	• Definitive studies have not been done • Insufficient data Table 5-1 • No data available • Animal data not supportive of reproductive/developmental effects • No chronic studies • Distribution studies have already shown that reproductive organs are not a likely target • Further studies are required usin relevant routes of exposure and dose response experiments to establish if at plausible maternal exposure levels, a significan foetal dose and effect occurs • Insufficient data • There were only two studies on this topic • This could be important but we simply do not know at this time • Some of our animal studies indicate transport to the pup • Little to no data • Usually at higher doses than other systemic routes so address that first, then reproduction and development	• Analytical Techniques 9(#); 29(%) • Control Technologies 5(#); 16(%) • MWCNT Processing Methods 4(#); 13(%) • MWCNT Purity 8(#); 26(%) • MWCNT Synthesis Methods 5(#); 16(%) • Personal Protective Equipment 7(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 10(#); 32(%) • Aggregation/Agglomeration State 13(#); 42(%) • Applied Coatings 12(#); 39(%) • Biodegradability 11(#); 35(%) • Catalytic Activity 10(#); 32(%) • Charge 10(#); 32(%) • Conductive or Magnetic Properties 5(#); 16(%) • Crystalline Phase 6(#); 19(%) • Lipophilicity 13(#); 42(%) • Matrix Bound vs. Free 13(#); 42(%) • Morphology (e.g. aspect ratio, length, width, shape) 14(#); 45(%) • Persistence 12(#); 39(%) • Redox Potential 11(#); 35(%) • Size/Size Distribution 13(#); 42(%) • Specific Surface Area 11(#); 35(%) • Structural Formula/Molecular Structure 9(#); 29(%) • Surface Chemistry 14(#); 45(%) • Water Solubility/Dispersibility 13(#); 42(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 5(#); 16(%) • Groundwater 5(#); 16(%) • Sediment 2(#); 6(%) • Soil 4(#); 13(%) • Surface Water 5(#); 16(%) • Wastewater 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 1(#); 3(%) • Temperature 2(#); 6(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 6(%) • Dispersing Agents 5(#); 16(%) • Dissolved Oxygen Content 1(#); 3(%) • Exposure to Sunlight 2(#); 6(%) • Heavy Metals in Environment 6(#); 19(%) • Ionic Strength in Environment 5(#); 16(%) • Ligand Concentrations in Environment 4(#); 13(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 6(#); 19(%) • pH 4(#); 13(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 2(#); 6(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 10(#); 32(%) • Bioaccumulation 10(#); 32(%) • Biomagnification 8(#); 26(%) • Microbial Communities in Environment 4(#); 13(%) • Organism Health 8(#); 26(%) • Species/Individual Developmental Behavior 8(#); 26(%) • Species/Individual Feeding Behavior 7(#); 23(%) • Species/Individual Reproductive Behavior 8(#); 26(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 13(#); 42(%) • Chronic Exposure 18(#); 58(%) • Exposure Route 18(#); 58(%) • Geographic Location (i.e. rural vs. urban) 5(#); 16(%) • Habitat Structure 6(#); 19(%) • Human Activity 10(#); 32(%) • Individual Activity Level 11(#); 35(%) • Life Stage 12(#); 39(%) • Occupation 13(#); 42(%) • Subchronic Exposure 15(#); 48(%) • Susceptible Populations/Individuals 17(#); 55(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
66	Aquatic Biota-Survival	15(#); 48(%)	11(#); 35(%)	5(#); 16(%)	11(#); 35(%)	3(#); 10(%)	1(#); 3(%)	3(#); 10(%)	6(#); 19(%)	6(#); 19(%)	• Data are available • Existing data documenting physical effects of MWCNT • Definitive studies have not been done • Incomplete data available • There are complexities in perfoming studies with particulates that do not generally form steady homogenous suspensions making interpretation of actual applied dose difficult and therefore the devlopment of an accurate dose-response relationship challenging. In addition, there are only limited studies available although several do exist. • Minimal effects are typically observed for sediment organisms, but various effects have been observed for water-dwelling organisms • If there are significant releases to surface water must be sure will not harm aquatic species • Little to no data	• Analytical Techniques 4(#); 13(%) • Control Technologies 3(#); 10(%) • MWCNT Processing Methods 3(#); 10(%) • MWCNT Purity 3(#); 10(%) • MWCNT Synthesis Methods 1(#); 3(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 19(%) • Aggregation/Agglomeration State 7(#); 23(%) • Applied Coatings 5(#); 16(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 3(#); 10(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 2(#); 6(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 5(#); 16(%) • Matrix Bound vs. Free 7(#); 23(%) • Morphology (e.g. aspect ratio, length, width, shape) 7(#); 23(%) • Persistence 6(#); 19(%) • Redox Potential 5(#); 16(%) • Size/Size Distribution 7(#); 23(%) • Specific Surface Area 5(#); 16(%) • Structural Formula/Molecular Structure 3(#); 10(%) • Surface Chemistry 6(#); 19(%) • Water Solubility/Dispersibility 7(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 3(%) • Groundwater 3(#); 10(%) • Sediment 4(#); 13(%) • Soil 1(#); 3(%) • Surface Water 6(#); 19(%) • Wastewater 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 6(%) • Light Availability 1(#); 3(%) • Soil Porosity 1(#); 3(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 3(#); 10(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 3(%) • Dispersing Agents 5(#); 16(%) • Dissolved Oxygen Content 4(#); 13(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 6(#); 19(%) • Ionic Strength in Environment 4(#); 13(%) • Ligand Concentrations in Environment 5(#); 16(%) • Natural Organic Matter (NOM) 6(#); 19(%) • Other Contaminants in Environment 7(#); 23(%) • pH 4(#); 13(%) • Protein Concentration in Environment 5(#); 16(%) • Salinity 4(#); 13(%) • Surfactant (in Lab) 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 16(%) • Bioaccumulation 6(#); 19(%) • Biomagnification 5(#); 16(%) • Microbial Communities in Environment 4(#); 13(%) • Organism Health 7(#); 23(%) • Species/Individual Developmental Behavior 4(#); 13(%) • Species/Individual Feeding Behavior 5(#); 16(%) • Species/Individual Reproductive Behavior 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 6(#); 19(%) • Chronic Exposure 7(#); 23(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 3(#); 10(%) • Habitat Structure 5(#); 16(%) • Human Activity 2(#); 6(%) • Individual Activity Level 1(#); 3(%) • Life Stage 6(#); 19(%) • Occupation 0(#); 0(%) • Subchronic Exposure 5(#); 16(%) • Susceptible Populations/Individuals 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
67	Aquatic B ota Developmenta	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	9(#) 29(%)	6(#) 19(%)	0(#) 0(%)	0(#) 0(%)	5(#) 16(%)	10(#) 32(%)	• Defin tive stud es have not been done • There are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t and therefore the dev opment of an accurate dose-response relationsh p cha eng ng • Data are ava ab e • ncomp ete data ava ab e • nsuff c ent data • Existing data suggesting energetics effects of nh b tion of food ass mi ation • There are a number of stud es on the weight changes of organ sms w th time but fewer on other top cs related to development • f there are s gn f cant releases to surface water must be sure w not harm aquatic spec es • L tt e to no data	• Ana ytica Techn ques 5(#) 16(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 2(#) 6(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 1(#) 3(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 16(%) • Aggregation/Agg omeration State 6(#) 19(%) • App ed Coatings 5(#) 16(%) • B odegradab ty 4(#) 13(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 7(#) 23(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 7(#) 23(%) • Pers stence 6(#) 19(%) • Redox Potentia 7(#) 23(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 7(#) 23(%) • Water So ub ty/D spers b ty 7(#) 23(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 3(%) • Groundwater 3(#) 10(%) • Sed ment 4(#) 13(%) • So 1(#) 3(%) • Surface Water 6(#) 19(%) • Wastewater 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 3(#) 10(%) • Temperature 3(#) 10(%) • W nd 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 4(#) 13(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 7(#) 23(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 6(#) 19(%) • Other Contaminants n Env ronment 7(#) 23(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 4(#) 13(%) • Surfactant (in Lab) 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 23(%) • B oaccumu ation 8(#) 26(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 5(#) 16(%) • Organ sm Hea th 8(#) 26(%) • Spec es/ nd v dua Developmenta Behav or 7(#) 23(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 16(%) • Spec es/ nd v dua Reproductive Behav or 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 19(%) • Chron c Exposure 9(#) 29(%) • Exposure Route 7(#) 23(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 6(#) 19(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 8(#) 26(%) • Occupation 1(#) 3(%) • Subchron c Exposure 6(#) 19(%) • Susceptib e Popu ations/ nd v dua s 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
68	Aquatic B ota Reproductive	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	9(#) 29(%)	6(#) 19(%)	0(#) 0(%)	1(#) 3(%)	4(#) 13(%)	10(#) 32(%)	• Data are ava ab e • Defin tive stud es have not been done • There are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t and therefore the dev opment of an accurate dose-response relationsh p cha eng ng n add tion there are on y mited stud es ava ab e a though severa do exist. • Few stud es are ava ab e on th s top c • nsuff c ent data • Existing data suggesting energetics effects of nh b tion of food ass mi ation • L tt e to no data • f there are s gn f cant releases to surface water must be sure w not harm aquatic spec es	• Ana ytica Techn ques 6(#) 19(%) • Contro Techno og es 3(#) 10(%) • MWCNT Process ng Methods 2(#) 6(%) • MWCNT Pur ty 3(#) 10(%) • MWCNT Synthes s Methods 1(#) 3(%) • Persona Protective Equ pment 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 19(%) • Aggregation/Agg omeration State 7(#) 23(%) • App ed Coatings 5(#) 16(%) • B odegradab ty 5(#) 16(%) • Cata ytic Activ ty 4(#) 13(%) • Charge 3(#) 10(%) • Conductive or Magnetic Properties 2(#) 6(%) • Crysta ne Phase 3(#) 10(%) • L poph c ty 7(#) 23(%) • Matr x Bound vs Free 8(#) 26(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 26(%) • Pers stence 6(#) 19(%) • Redox Potentia 7(#) 23(%) • S ze/S ze D str bution 7(#) 23(%) • Spec f c Surface Area 5(#) 16(%) • Structura Formu a/Mo ecu ar Structure 4(#) 13(%) • Surface Chem stry 8(#) 26(%) • Water So ub ty/D spers b ty 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 3(%) • Groundwater 3(#) 10(%) • Sed ment 5(#) 16(%) • So 1(#) 3(%) • Surface Water 7(#) 23(%) • Wastewater 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 1(#) 3(%) • So Poros ty 1(#) 3(%) • So /Sed ment Fractionation 4(#) 13(%) • Temperature 3(#) 10(%) • W nd 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 5(#) 16(%) • D sso ved Oxygen Content 4(#) 13(%) • Exposure to Sun ght 1(#) 3(%) • Heavy Meta s n Env ronment 7(#) 23(%) • on c Strength n Env ronment 4(#) 13(%) • L gand Concentrations n Env ronment 6(#) 19(%) • Natura Organ c Matter (NOM) 7(#) 23(%) • Other Contaminants n Env ronment 7(#) 23(%) • pH 4(#) 13(%) • Protein Concentration n Env ronment 5(#) 16(%) • Sa n ty 5(#) 16(%) • Surfactant (in Lab) 6(#) 19(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 23(%) • B oaccumu ation 8(#) 26(%) • B omagn f cation 7(#) 23(%) • M crob a Commun ties n Env ronment 5(#) 16(%) • Organ sm Hea th 9(#) 29(%) • Spec es/ nd v dua Developmenta Behav or 6(#) 19(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 19(%) • Spec es/ nd v dua Reproductive Behav or 8(#) 26(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 19(%) • Chron c Exposure 10(#) 32(%) • Exposure Route 8(#) 26(%) • Geograph c Location (i.e. rura vs urban) 3(#) 10(%) • Hab tat Structure 6(#) 19(%) • Human Activ ty 3(#) 10(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 9(#) 29(%) • Occupation 1(#) 3(%) • Subchron c Exposure 7(#) 23(%) • Susceptib e Popu ations/ nd v dua s 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
69	Aquatic B ota Other Sub etha Endpo nts	15(#) 48(%)	11(#) 35(%)	5(#) 16(%)	5(#) 16(%)	5(#) 16(%)	5(#) 16(%)	0(#) 0(%)	5(#) 16(%)	10(#) 32(%)	• f t cannot surv ve, develop or reproduce…what else s there? • ncomp ete data ava ab e • L ke what endpo nts? • Few stud es are ava ab e on th s top c • nsuff c ent data • Existing data suggesting energetics effects of nh b tion of food ass mi ation • Poss b e endocr ne d sruptors • L tt e to no data	• Ana ytica Techn ques 3(#) 10(%) • Contro Techno og es 2(#) 6(%) • MWCNT Process ng Methods 1(#) 3(%) • MWCNT Pur ty 2(#) 6(%) • MWCNT Synthes s Methods 1(#) 3(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 4(#) 13(%) • Aggregation/Agg omeration State 5(#) 16(%) • App ed Coatings 3(#) 10(%) • B odegradab ty 3(#) 10(%) • Cata ytic Activ ty 2(#) 6(%) • Charge 2(#) 6(%) • Conductive or Magnetic Properties 1(#) 3(%) • Crysta ne Phase 1(#) 3(%) • L poph c ty 3(#) 10(%) • Matr x Bound vs Free 5(#) 16(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 16(%) • Pers stence 3(#) 10(%) • Redox Potentia 4(#) 13(%) • S ze/S ze D str bution 4(#) 13(%) • Spec f c Surface Area 3(#) 10(%) • Structura Formu a/Mo ecu ar Structure 3(#) 10(%) • Surface Chem stry 5(#) 16(%) • Water So ub ty/D spers b ty 5(#) 16(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 1(#) 3(%) • Sed ment 3(#) 10(%) • So 0(#) 0(%) • Surface Water 4(#) 13(%) • Wastewater 2(#) 6(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 6(%) • L ght Ava ab ty 0(#) 0(%) • So Poros ty 0(#) 0(%) • So /Sed ment Fractionation 2(#) 6(%) • Temperature 2(#) 6(%) • W nd 1(#) 3(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 3(%) • D spers ng Agents 2(#) 6(%) • D sso ved Oxygen Content 2(#) 6(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 4(#) 13(%) • on c Strength n Env ronment 1(#) 3(%) • L gand Concentrations n Env ronment 3(#) 10(%) • Natura Organ c Matter (NOM) 4(#) 13(%) • Other Contaminants n Env ronment 4(#) 13(%) • pH 2(#) 6(%) • Protein Concentration n Env ronment 2(#) 6(%) • Sa n ty 2(#) 6(%) • Surfactant (in Lab) 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 10(%) • B oaccumu ation 4(#) 13(%) • B omagn f cation 3(#) 10(%) • M crob a Commun ties n Env ronment 2(#) 6(%) • Organ sm Hea th 6(#) 19(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 13(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 13(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 13(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 3(#) 10(%) • Chron c Exposure 6(#) 19(%) • Exposure Route 4(#) 13(%) • Geograph c Location (i.e. rura vs urban) 2(#) 6(%) • Hab tat Structure 2(#) 6(%) • Human Activ ty 2(#) 6(%) • nd v dua Activ ty Level 2(#) 6(%) • L fe Stage 5(#) 16(%) • Occupation 1(#) 3(%) • Subchron c Exposure 4(#) 13(%) • Susceptib e Popu ations/ nd v dua s 3(#) 10(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
70	Terrestrial Biota-Survival	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	7(#); 23(%)	2(#); 6(%)	0(#); 0(%)	0(#); 0(%)	3(#); 10(%)	6(#); 19(%)	• Definitive studies have not been done • Incomplete data available • More likely to end up in soil; potential for antimicrobial effects • There have been a number of plant studies which show toxic effects at high concentrations and a lack of mortality in earthworm studies but decreased survival with some microorganism studies • Little to no data	• Analytical Techniques 4(#); 13(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 3(#); 10(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 3(#); 10(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 3(#); 10(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 1(#); 3(%) • Sediment 1(#); 3(%) • Soil 4(#); 13(%) • Surface Water 3(#); 10(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 1(#); 3(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 3(#); 10(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 3(#); 10(%) • Other Contaminants in Environment 3(#); 10(%) • pH 2(#); 6(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 3(#); 10(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 2(#); 6(%) • Species/Individual Feeding Behavior 3(#); 10(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 13(%) • Chronic Exposure 5(#); 16(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 3(#); 10(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 3(#); 10(%) • Occupation 0(#); 0(%) • Subchronic Exposure 4(#); 13(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
71	Terrestrial Biota-Developmental	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	6(#); 19(%)	3(#); 10(%)	0(#); 0(%)	0(#); 0(%)	3(#); 10(%)	6(#); 19(%)	• Definitive studies have not been done • Incomplete data available • More likely to end up in soil; potential for antimicrobial effects • There have been some studies on this with plant growth and root and shoot length, but fewer studies on other organisms except for one study on bacteria in soils • Little to no data	• Analytical Techniques 4(#); 13(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 13(%) • Aggregation/Agglomeration State 3(#); 10(%) • Applied Coatings 3(#); 10(%) • Biodegradability 4(#); 13(%) • Catalytic Activity 3(#); 10(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 4(#); 13(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 13(%) • Persistence 4(#); 13(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 3(#); 10(%) • Water Solubility/Dispersibility 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 1(#); 3(%) • Sediment 1(#); 3(%) • Soil 4(#); 13(%) • Surface Water 3(#); 10(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 3(#); 10(%) • Temperature 1(#); 3(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 3(#); 10(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 3(#); 10(%) • Other Contaminants in Environment 3(#); 10(%) • pH 2(#); 6(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 3(#); 10(%) • Organism Health 3(#); 10(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 2(#); 6(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 13(%) • Chronic Exposure 5(#); 16(%) • Exposure Route 5(#); 16(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 3(#); 10(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 3(#); 10(%) • Occupation 0(#); 0(%) • Subchronic Exposure 4(#); 13(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
72	Terrestrial Biota-Reproductive	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	5(#); 16(%)	4(#); 13(%)	0(#); 0(%)	0(#); 0(%)	2(#); 6(%)	7(#); 23(%)	• Definitive studies have not been done • Few studies are available on this topic • Incomplete data • More likely to end up in soil, not enough data	• Analytical Techniques 5(#); 16(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 1(#); 3(%) • MWCNT Purity 1(#); 3(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 16(%) • Aggregation/Agglomeration State 4(#); 13(%) • Applied Coatings 3(#); 10(%) • Biodegradability 5(#); 16(%) • Catalytic Activity 3(#); 10(%) • Charge 2(#); 6(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 2(#); 6(%) • Lipophilicity 4(#); 13(%) • Matrix Bound vs. Free 5(#); 16(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 16(%) • Persistence 4(#); 13(%) • Redox Potential 3(#); 10(%) • Size/Size Distribution 3(#); 10(%) • Specific Surface Area 3(#); 10(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 4(#); 13(%) • Water Solubility/Dispersibility 5(#); 16(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 1(#); 3(%) • Sediment 2(#); 6(%) • Soil 4(#); 13(%) • Surface Water 4(#); 13(%) • Wastewater 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 3(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 4(#); 13(%) • Temperature 1(#); 3(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 3(#); 10(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 3(%) • Heavy Metals in Environment 3(#); 10(%) • Ionic Strength in Environment 2(#); 6(%) • Ligand Concentrations in Environment 2(#); 6(%) • Natural Organic Matter (NOM) 4(#); 13(%) • Other Contaminants in Environment 3(#); 10(%) • pH 2(#); 6(%) • Protein Concentration in Environment 3(#); 10(%) • Salinity 1(#); 3(%) • Surfactant (in Lab) 3(#); 10(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 13(%) • Bioaccumulation 4(#); 13(%) • Biomagnification 4(#); 13(%) • Microbial Communities in Environment 3(#); 10(%) • Organism Health 4(#); 13(%) • Species/Individual Developmental Behavior 3(#); 10(%) • Species/Individual Feeding Behavior 3(#); 10(%) • Species/Individual Reproductive Behavior 4(#); 13(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 13(%) • Chronic Exposure 6(#); 19(%) • Exposure Route 6(#); 19(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 3(#); 10(%) • Human Activity 1(#); 3(%) • Individual Activity Level 0(#); 0(%) • Life Stage 4(#); 13(%) • Occupation 0(#); 0(%) • Subchronic Exposure 5(#); 16(%) • Susceptible Populations/Individuals 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
73	Terrestrial Biota-Other Sublethal Endpoints	9(#); 29(%)	16(#); 52(%)	6(#); 19(%)	2(#); 6(%)	3(#); 10(%)	4(#); 13(%)	0(#); 0(%)	1(#); 3(%)	8(#); 26(%)	• If it cannot survive, develop or reproduce…what else is there? • Incomplete data available • Few studies are available on this topic • More likely to end up in soil, not enough data	• Analytical Techniques 2(#); 6(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 6(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 1(#); 3(%) • Biodegradability 2(#); 6(%) • Catalytic Activity 1(#); 3(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 2(#); 6(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 2(#); 6(%) • Soil 1(#); 3(%) • Surface Water 1(#); 3(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 3(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 1(#); 3(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 2(#); 6(%) • Exposure Route 2(#); 6(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 3(%) • Occupation 0(#); 0(%) • Subchronic Exposure 2(#); 6(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
74	Other-Economic	10(#); 32(%)	10(#); 32(%)	11(#); 35(%)	5(#); 16(%)	4(#); 13(%)	1(#); 3(%)	0(#); 0(%)	4(#); 13(%)	6(#); 19(%)	• Applications unknown, so benefits/risk balance is unknown. There could be more benefits to using the technology vs. not using it • Little data presented or seems to be available • Incomplete information available about the process and material to be pursued • Important trade-off between ways to treat textiles • Little to no data	• Analytical Techniques 0(#); 0(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 2(#); 6(%) • MWCNT Purity 2(#); 6(%) • MWCNT Synthesis Methods 2(#); 6(%) • Personal Protective Equipment 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 2(#); 6(%) • Biodegradability 1(#); 3(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 3(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 3(%) • Persistence 1(#); 3(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 3(%) • Specific Surface Area 1(#); 3(%) • Structural Formula/Molecular Structure 1(#); 3(%) • Surface Chemistry 1(#); 3(%) • Water Solubility/Dispersibility 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 3(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 2(#); 6(%) • Human Activity 2(#); 6(%) • Individual Activity Level 1(#); 3(%) • Life Stage 0(#); 0(%) • Occupation 2(#); 6(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
75	Other-Societal	10(#); 32(%)	10(#); 32(%)	11(#); 35(%)	5(#); 16(%)	4(#); 13(%)	1(#); 3(%)	1(#); 3(%)	4(#); 13(%)	5(#); 16(%)	• Public may have inflated view of risk • Applications unknown, so benefits/risk balance is unknown. There could be more benefits to using the technology vs. not using it. • Little data presented or seems to be available • Incomplete information available about the process and material to be pursued • Little to no data	• Analytical Techniques 0(#); 0(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 3(%) • Chronic Exposure 1(#); 3(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 2(#); 6(%) • Habitat Structure 2(#); 6(%) • Human Activity 2(#); 6(%) • Individual Activity Level 1(#); 3(%) • Life Stage 1(#); 3(%) • Occupation 2(#); 6(%) • Subchronic Exposure 1(#); 3(%) • Susceptible Populations/Individuals 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
76	Other-Environmental Resources	10(#); 32(%)	10(#); 32(%)	11(#); 35(%)	6(#); 19(%)	3(#); 10(%)	1(#); 3(%)	1(#); 3(%)	4(#); 13(%)	5(#); 16(%)	• Incomplete information available about the process and material to be pursued • Life time may be too short through oxidation and coagulation • Until you know how it will be used and how it may/may not get into the environment to impact other resources, really can't make any input on this. • Little to no data	• Analytical Techniques 1(#); 3(%) • Control Technologies 1(#); 3(%) • MWCNT Processing Methods 4(#); 13(%) • MWCNT Purity 4(#); 13(%) • MWCNT Synthesis Methods 3(#); 10(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 3(%) • Aggregation/Agglomeration State 1(#); 3(%) • Applied Coatings 2(#); 6(%) • Biodegradability 2(#); 6(%) • Catalytic Activity 1(#); 3(%) • Charge 1(#); 3(%) • Conductive or Magnetic Properties 1(#); 3(%) • Crystalline Phase 1(#); 3(%) • Lipophilicity 1(#); 3(%) • Matrix Bound vs. Free 2(#); 6(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 6(%) • Persistence 2(#); 6(%) • Redox Potential 1(#); 3(%) • Size/Size Distribution 2(#); 6(%) • Specific Surface Area 2(#); 6(%) • Structural Formula/Molecular Structure 2(#); 6(%) • Surface Chemistry 2(#); 6(%) • Water Solubility/Dispersibility 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 6(%) • Groundwater 2(#); 6(%) • Sediment 2(#); 6(%) • Soil 2(#); 6(%) • Surface Water 2(#); 6(%) • Wastewater 2(#); 6(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 3(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 6(%) • Soil/Sediment Fractionation 2(#); 6(%) • Temperature 1(#); 3(%) • Wind 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 6(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 3(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 3(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 3(%) • Bioaccumulation 2(#); 6(%) • Biomagnification 2(#); 6(%) • Microbial Communities in Environment 2(#); 6(%) • Organism Health 1(#); 3(%) • Species/Individual Developmental Behavior 1(#); 3(%) • Species/Individual Feeding Behavior 1(#); 3(%) • Species/Individual Reproductive Behavior 1(#); 3(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 3(#); 10(%) • Habitat Structure 2(#); 6(%) • Human Activity 2(#); 6(%) • Individual Activity Level 1(#); 3(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

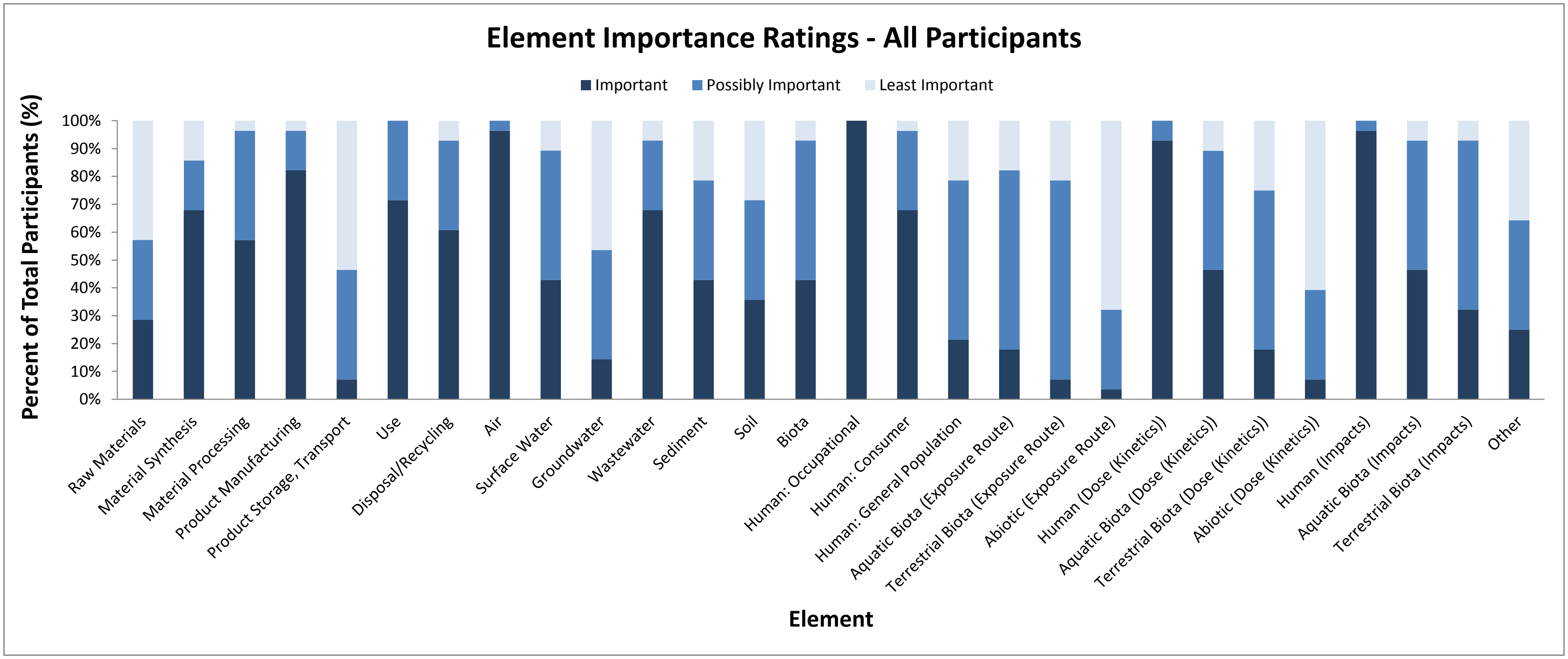
Appendix E
Results from Round 2

Appendix E: Results from Round 2

Contents:

1. Group Results: Element Importance Stacked Bar Chart
2. Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (E-RRF) Pairs
3. Group-Wide CEA Level-Specific Bar Charts
4. Group Results: Table (with Influential Factors)

1. Group Results: Element Importance Stacked Bar Chart


Element Importance Ratings - All Participants
Important
Possibly Important
Least Important
Percent of Total Participants (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Raw Materials
Material Synthesis
Material Processing
Product Manufacturing
Product Storage, Transport
Use
Disposal/Recycling
Air
Surface Water
Groundwater
Wastewater
Sediment
Soil
Biota
Human: Occupational
Human: Consumer
Human: General Population
Aquatic Biota (Exposure Route)
Terrestrial Biota (Exposure Route)
Abiotic (Exposure Route)
Human (Dose (Kinetics))
Aquatic Biota (Dose (Kinetics))
Terrestrial Biota (Dose (Kinetics))
Abiotic (Dose (Kinetics))
Human (Impacts)
Aquatic Biota (Impacts)
Terrestrial Biota (Impacts)
Other
Element

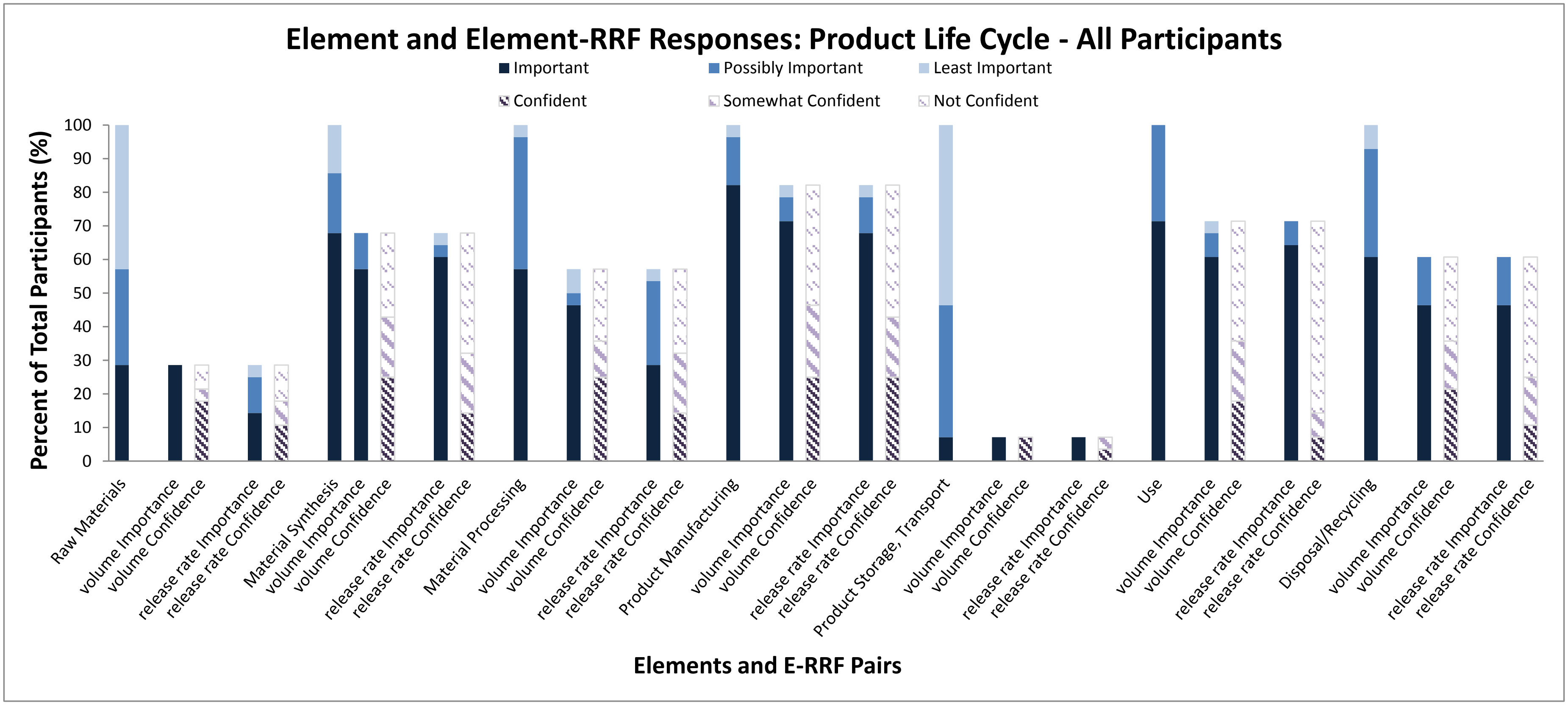
2. Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (E-RRF) Pairs

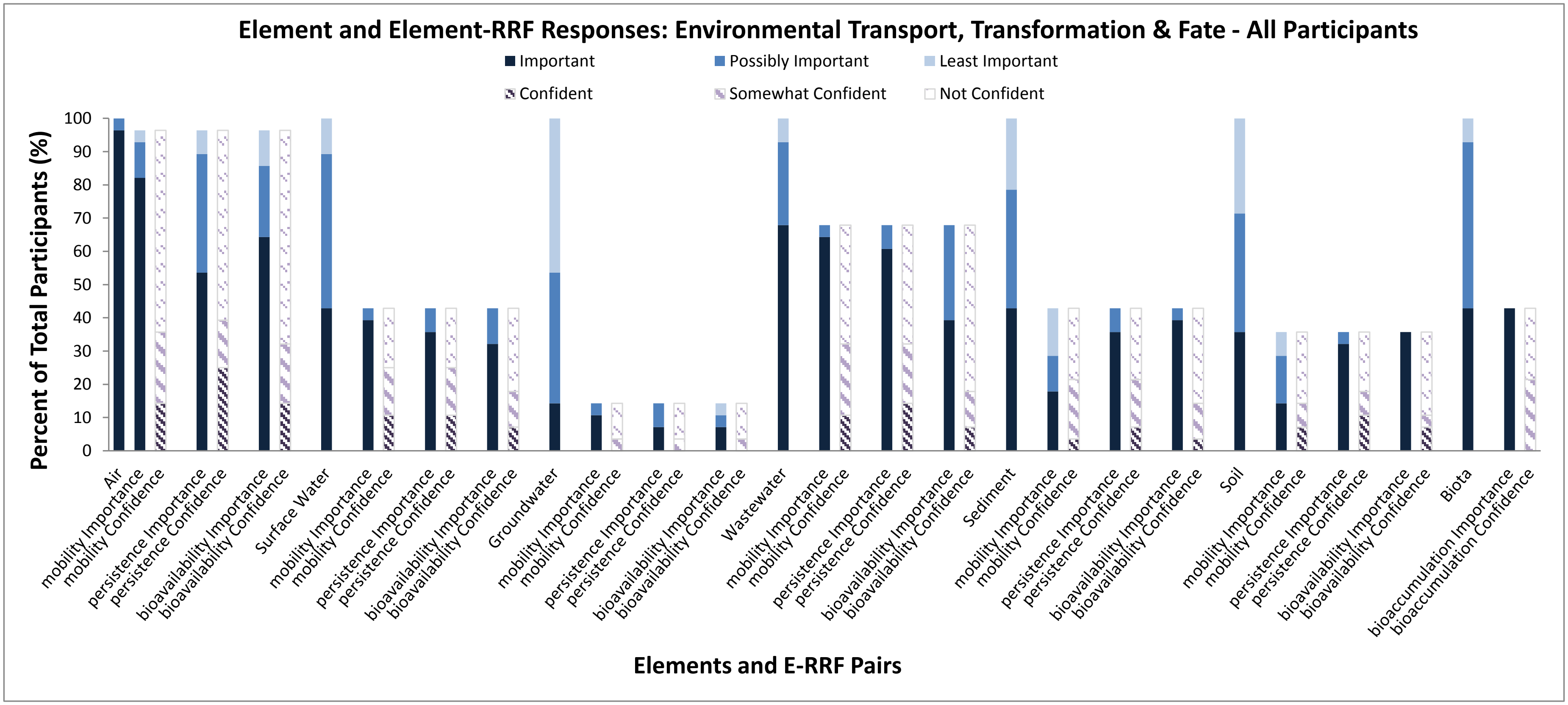
Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (RRF) Pairs - All Participants

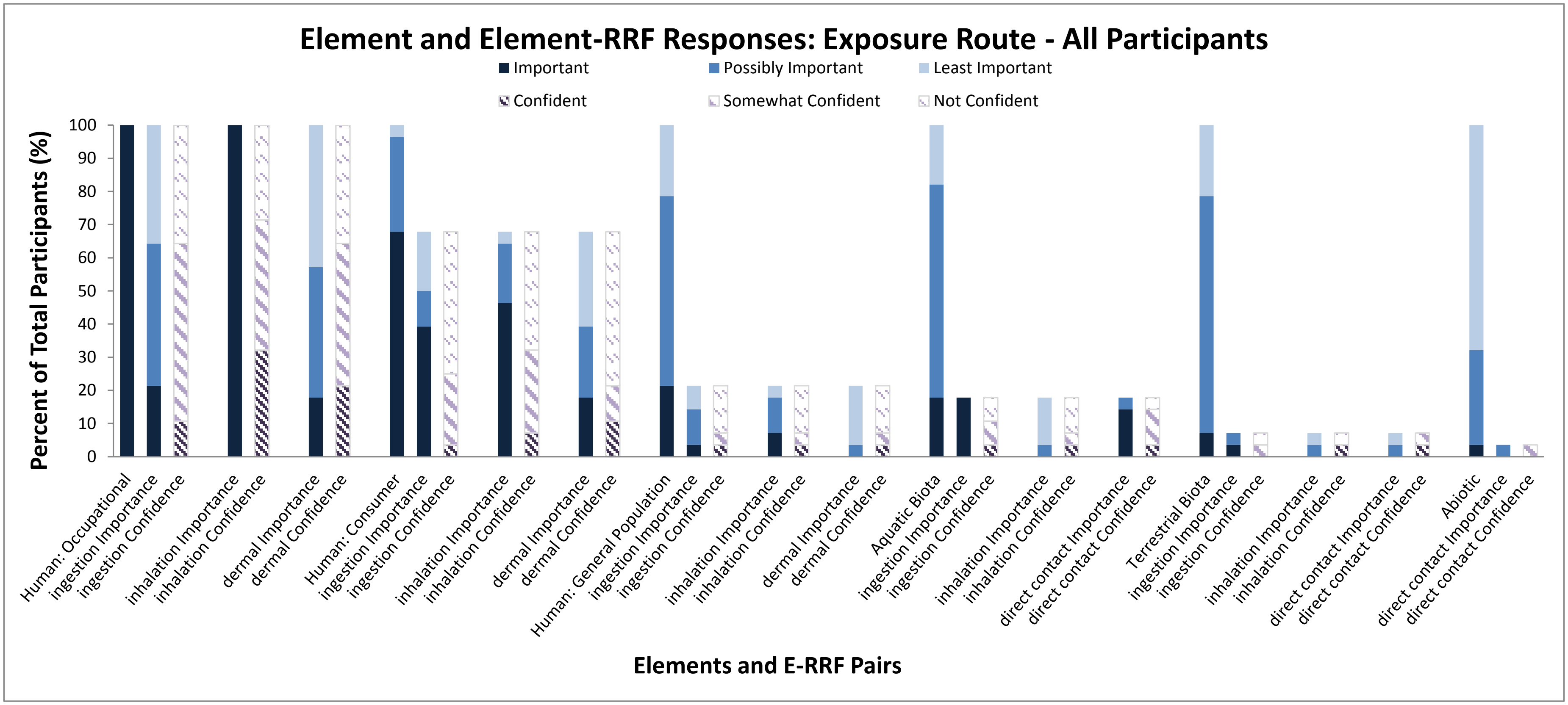
*I: %; C: % represents the percentage of total respondents who chose the cell's Importance and Confidence responses, respectively, for the listed Element-Risk Relevance Factor.

	Confident	Somewhat Confident	Not Confident
Important	• Product Life Cycle-Material Processing-Volume, I: 46%; C: 25%	• Exposure Route-Human: Occupational-Inhalation, I: 100%; C: 39% • Impacts-Aquatic Biota-Survival, I: 36%; C: 25%	• Product Life Cycle Material Synthesis Volume, I: 57%; C: 25% • Product Life Cyc e Mater a Synthes s Re ease Rate, I: 61%; C: 36% • Product Life Cyc e Mater a Process ng-Re ease Rate, I: 29%; C: 25% • Product L fe Cycle Product Manufactur ng Vo ume, I: 71%; C: 36% • Product L fe Cycle Product Manufactur ng Re ease Rate, I: 68%; C: 39% • Product Life Cycle Use Volume, I: 61%; C: 36% • Product Life Cycle Use Release Rate, I: 64%; C: 57% • Product L fe Cycle D sposa /Recycl ng Vo ume, I: 46%; C: 25% • Product L fe Cycle D sposa /Recycl ng Re ease Rate, I: 46%; C: 36% • Env. TT&F Air Mobility, I: 82%; C: 61% • Env. TT&F Air Persistence, I: 54%; C: 57% • Env. TT&F Air Bioavailability, I: 64%; C: 64% • Env. TT&F Wastewater Mobility, I: 64%; C: 36% • Env. TT&F Wastewater Persistence, I: 61%; C: 36% • Env. TT&F Wastewater Bioavailability, I: 39%; C: 50% • Env. TT&F Sediment Mobility, I: 18%; C: 21% • Env. TT&F Sediment Persistence, I: 36%; C: 21% • Env. TT&F Sediment Bioavailability, I: 39%; C: 29% • Env. TT&F Soil Mobility, I: 14%; C: 21% • Env. TT&F Soil Persistence, I: 32%; C: 18% • Env. TT&F Soil Bioavailability, I: 36%; C: 25% • Exposure Route Human: Consumer Ingestion, I: 39%; C: 43% • Exposure Route Human: Consumer Inha at on, I: 46%; C: 36% • Dose (Kinetics)-Human Absorption, I: 79%; C: 64% • Dose (Kinetics)-Human Distribution, I: 71%; C: 64% • Dose (Kinetics)-Human Metabolism, I: 43%; C: 68% • Dose (Kinetics)-Human Excretion, I: 57%; C: 64% • Dose (Kinetics)-Aquatic Biota Absorption, I: 43%; C: 21% • Dose (Kinetics)-Aquatic Biota Distribution, I: 43%; C: 32% • Dose (Kinetics)-Aquatic Biota Excretion, I: 32%; C: 29% • Impacts Human Cancer, I: 82%; C: 50% • Impacts Human Non cancer, I: 64%; C: 39% • Impacts Aquatic Biota Developmental, I: 36%; C: 32% • Impacts Aquat c B ota Reproduct ve, I: 32%; C: 32% • Impacts Aquat c B ota Other Sub etha Endpo nts, I: 21%; C: 36%
Possibly Important		• Exposure Route-Human: Occupational-Ingestion, I: 43%; C: 54%	• Impacts-Human-Reproductive/ Developmental, I: 50%; C: 79%
Least Important		• Exposure Route-Human: Occupational-Dermal, I: 43%; C: 43%	• Exposure Route-Human: Consumer-Dermal, I: 29%; C: 46% • Dose (Kinetics)-Aquatic Biota-Metabolism, I: 25%; C: 36%

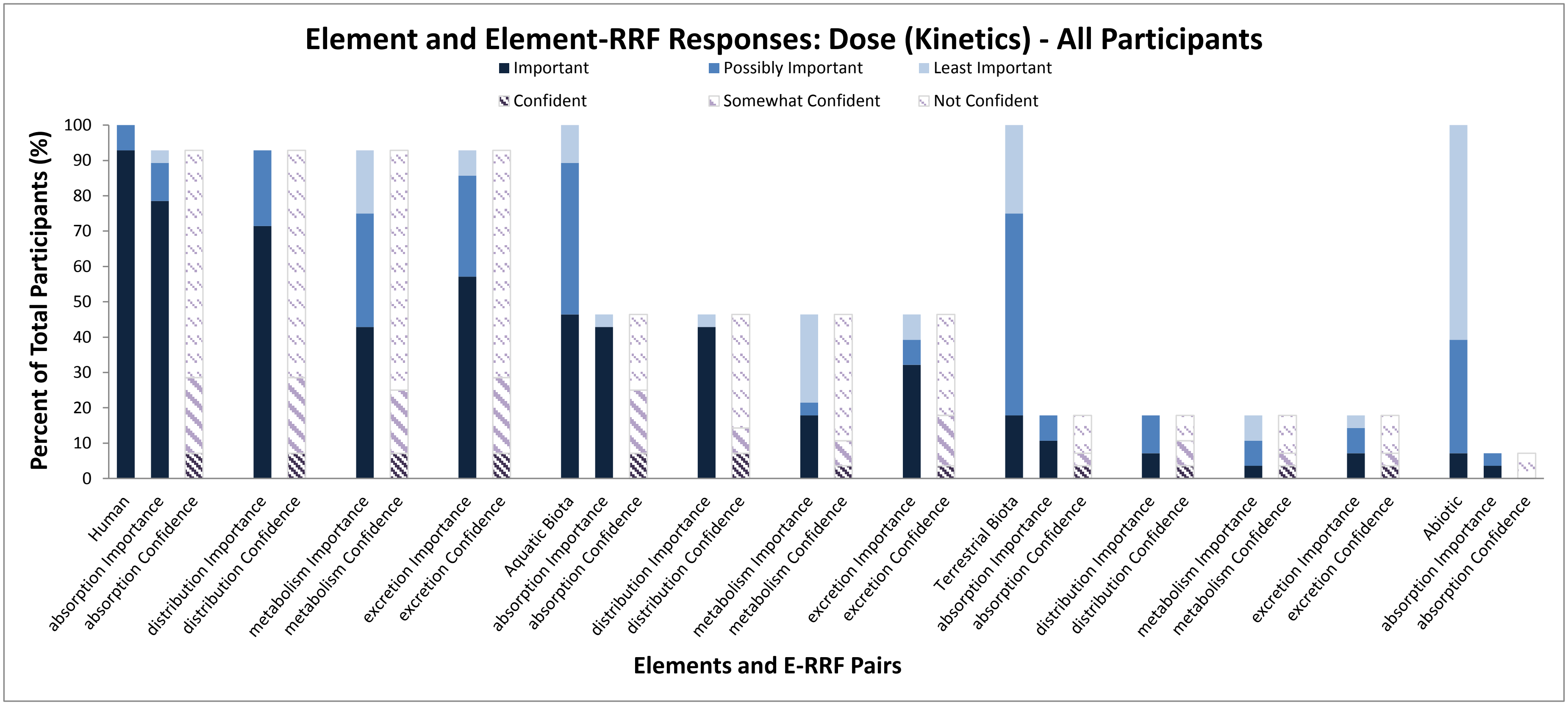
3. Group-Wide CEA Level-Specific Bar Charts


Element and Element-RRF Responses: Product Life Cycle - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Raw Materials
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Synthesis
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Processing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Manufacturing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Storage, Transport
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Use
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Disposal/Recycling
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Elements and E-RRF Pairs

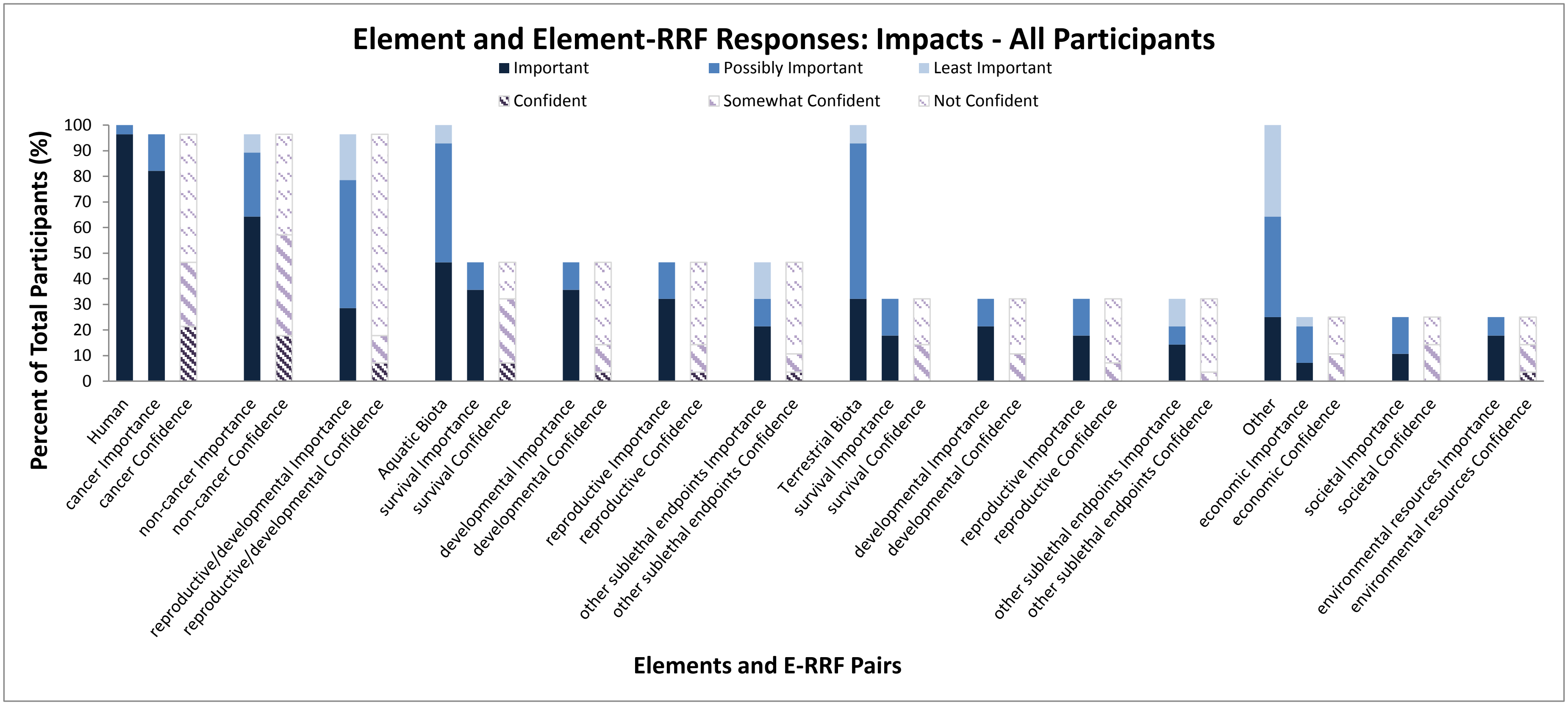

Element and Element-RRF Responses: Environmental Transport, Transformation & Fate - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Air
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Surface Water
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Groundwater
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Wastewater
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Sediment
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Soil
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Biota
bioaccumulation Importance
bioaccumulation Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Exposure Route - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Human: Occupational
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: Consumer
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: General Population
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Aquatic Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Terrestrial Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Abiotic
direct contact Importance
direct contact Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Dose (Kinetics) - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Human
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Aquatic Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Terrestrial Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Abiotic
absorption Importance
absorption Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Impacts - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Human
cancer Importance
cancer Confidence
non-cancer Importance
non-cancer Confidence
reproductive/developmental Importance
reproductive/developmental Confidence
Aquatic Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Terrestrial Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Other
economic Importance
economic Confidence
societal Importance
societal Confidence
environmental resources Importance
environmental resources Confidence
Elements and E-RRF Pairs

4. Group Results: Table (with Influential Factors)

Please refer to **Figure 8** in the Summary Report for an overview and explanation of the color-coding of the rows in this table. For example, red rows indicate that the row's Element-Risk Relevance Factor (E-RRF) pair is grouped in the "Important" and "Not Confident" bin of the Importance/Confidence Matrix of E-RRF pairs.

* Represents the number and percentage of participants who ranked the row's Element-Risk Relevance Factor (E-RRF) Pair with the corresponding column's selection.

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
1	Raw Materials-Volume	8(#); 29(%)*	8(#); 29(%)	12(#); 43(%)	8(#); 29(%)	0(#); 0(%)	0(#); 0(%)	5(#); 18(%)	1(#); 4(%)	2(#); 7(%)	• essential for exposure analysis • Need to be able to identify impurities including amounts • proportional to exposure • Lack of published data on quantities manufactured or imported. • Uses of MWCNT not at all well defined. • need to completely characterize raw material to know what is being released	• Analytical Techniques 1(#); 4(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 2(#); 7(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 2(#); 7(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 2(#); 7(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 2(#); 7(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 2(#); 7(%) • Groundwater 2(#); 7(%) • Sediment 2(#); 7(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 1(#); 4(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 4(%) • pH 2(#); 7(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 2(#); 7(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 1(#); 4(%) • Occupation 2(#); 7(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
2	Raw Materials-Release Rate	8(#); 29(%)	8(#); 29(%)	12(#); 43(%)	4(#); 14(%)	3(#); 11(%)	1(#); 4(%)	3(#); 11(%)	2(#); 7(%)	3(#); 11(%)	• essential for exposure analysis • proportional to exposure • Due to increase in permitting and safety requirements for just about any product these days, highly unlikely that release of the material will be allowed at all. • Lack of published data on quantities manufactured or imported. • lack of release data	• Analytical Techniques 2(#); 7(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 1(#); 4(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 2(#); 7(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 1(#); 4(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 1(#); 4(%) • Sediment 1(#); 4(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 0(#); 0(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 4(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 1(#); 4(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
3	Material Synthesis-Volume	19(#); 68(%)	5(#); 18(%)	4(#); 14(%)	16(#); 57(%)	3(#); 11(%)	0(#); 0(%)	7(#); 25(%)	5(#); 18(%)	7(#); 25(%)	• essential for exposure analysis • First Principles • Need to estimate exposures • proportional to exposure • Lack of published data on quantities manufactured or imported. • Manufacturers rarely reveal this information yet this information informs modeling about potential concentrations in the environment • Proportion of MWCNT made during synthesis is unclear. Contamination level can vary between samples. • Uses of MWCNT not at all well defined. Further, how to incorporate them into various products varies greatly. • estimates can be made from manufacturer data if made available • The volume of production influences the potential for exposure and therefore is important information to have. Volume production information is in existance but due to the lack of reporting schemes, may be an underestimation. • This is no relevent volume data available yet. The concern would be for risks of high volumes of MWNTs (and byproducts) being produced, which has yet to occur on significant scale. • The rates have not been established • Market predictions for the size of the MWCNT market vary by orders of magnitude and will likely change further as we get more familiar with the technology. Ultimate volume is hard to estimate at present. (Note: It is the product of volume and release rate that is most important, neither is more important than the other or tells a full risk story without the other.) • Data from small scale R&D facilities only	• Analytical Techniques 6(#); 21(%) • Control Technologies 8(#); 29(%) • MWCNT Processing Methods 9(#); 32(%) • MWCNT Purity 8(#); 29(%) • MWCNT Synthesis Methods 10(#); 36(%) • Personal Protective Equipment 6(#); 21(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 14(%) • Aggregation/Agglomeration State 8(#); 29(%) • Applied Coatings 7(#); 25(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 4(#); 14(%) • Charge 6(#); 21(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 2(#); 7(%) • Lipophilicity 3(#); 11(%) • Matrix Bound vs. Free 7(#); 25(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 21(%) • Persistence 2(#); 7(%) • Redox Potential 4(#); 14(%) • Size/Size Distribution 7(#); 25(%) • Specific Surface Area 6(#); 21(%) • Structural Formula/Molecular Structure 4(#); 14(%) • Surface Chemistry 5(#); 18(%) • Water Solubility/Dispersibility 6(#); 21(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 8(#); 29(%) • Groundwater 2(#); 7(%) • Sediment 2(#); 7(%) • Soil 3(#); 11(%) • Surface Water 1(#); 4(%) • Wastewater 6(#); 21(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 3(#); 11(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 1(#); 4(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 3(#); 11(%) • Dispersing Agents 8(#); 29(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 2(#); 7(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 2(#); 7(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 2(#); 7(%) • pH 2(#); 7(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 6(#); 21(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 11(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 4(#); 14(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 8(#); 29(%) • Chronic Exposure 8(#); 29(%) • Exposure Route 7(#); 25(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 1(#); 4(%) • Human Activity 5(#); 18(%) • Individual Activity Level 6(#); 21(%) • Life Stage 1(#); 4(%) • Occupation 6(#); 21(%) • Subchronic Exposure 5(#); 18(%) • Susceptible Populations/Individuals 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
4	Mater a Synthes s Release Rate	19(#) 68(%)	5(#) 18(%)	4(#) 14(%)	17(#) 61(%)	1(#) 4(%)	1(#) 4(%)	4(#) 14(%)	5(#) 18(%)	10(#) 36(%)	• essentia for exposure ana ys s • F rst Pr nc p es • proportiona to exposure • Hard to estimate for fu sca e production fac ties • ack of pub shed data on quantities manufactured or mported • L tt e nformation s ava ab e about th s step for d fferent synthes s approaches • potentia for release unknown • Release rate (and partic e character stics) s very mportant n estimating potentia for exposure of production workers yet a most no nformation exists espec a y n mass production fac ties greatest cha enges are n mon tor ng techn ques • Release evels can be approximated fa r y wel • Wh e existing ndustr a processes w kely be adequate to conta n hazards assoc ated w th mater a release dur ng MWNT synthes s at h gh vo umes the r sk wou d ncrease and new methods such as h gh vo ume HEPA f ter ng may need to be emp oyed f the r sk of MWNTs and byproducts released dur ng MWNT synthes s s s gn f cant. • Due to ncrease n permitt ng and safety requ rements for ust about any product these days h gh y un kely that release of the mater a w be a owed at a • ack of release data • The mited resu ts from abs nd cate a prob em however production fac ties shou d be tighter • Release rates n commerc a fac ties w probab y be more contro ed than n other downstream stages Wh e not tota y conf dent, am somewhat conf dence that we can udge th s because th s s an has a ready been stud ed by many experts n var ous settings Know ng the release rate s mportant for r sk but my expectation s that manufacturers w do a reasonab e ob of keep ng th s under contro • Data from sma sca e R&D fac ties on y	• Ana ytica Techn ques 10(#) 36(%) • Contro Techno og es 10(#) 36(%) • MWCNT Process ng Methods 7(#) 25(%) • MWCNT Pur ty 7(#) 25(%) • MWCNT Synthes s Methods 10(#) 36(%) • Persona Protective Equ pment 8(#) 29(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 11(#) 39(%) • App ed Coatings 7(#) 25(%) • B odegradab ty 2(#) 7(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 5(#) 18(%) • Conductive or Magnetic Properties 1(#) 4(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 10(#) 36(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 5(#) 18(%) • Redox Potentia 3(#) 11(%) • S ze/S ze D str bution 8(#) 29(%) • Spec f c Surface Area 8(#) 29(%) • Structura Formu a/Mo ecu ar Structure 3(#) 11(%) • Surface Chem stry 6(#) 21(%) • Water So ub ty/D spers b ty 7(#) 25(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 8(#) 29(%) • Groundwater 3(#) 11(%) • Sed ment 3(#) 11(%) • So 5(#) 18(%) • Surface Water 2(#) 7(%) • Wastewater 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 0(#) 0(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 1(#) 4(%) • W nd 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 7(#) 25(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 1(#) 4(%) • L gand Concentrations n Env ronment 0(#) 0(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 1(#) 4(%) • pH 2(#) 7(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 5(#) 18(%) • B omagn f cation 4(#) 14(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 9(#) 32(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 7(#) 25(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 6(#) 21(%) • nd v dua Activ ty Level 7(#) 25(%) • L fe Stage 1(#) 4(%) • Occupation 7(#) 25(%) • Subchron c Exposure 6(#) 21(%) • Susceptib e Popu ations/ nd v dua s 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
5	Material Processing-Volume	16(#); 57(%)	11(#); 39(%)	1(#); 4(%)	13(#); 46(%)	1(#); 4(%)	2(#); 7(%)	7(#); 25(%)	3(#); 11(%)	6(#); 21(%)	• essential for exposure analysis • First Principles • proportional to exposure • If the volumes of strong acids, etc. that may be required for MWNT processing (purification, functionalization) are significant then it may pose a risk to the environment in terms of energy used and waste generated. Specific processes that will be required did not seem to be well known in the information provided. • Uses of MWCNT not well known which would drive volume. Could be large amounts, could be niche small amounts. • very little data available; processes are not mature • exposure-relevant • Important to know how many workers might be potentially exposed • Many questions about purifcation used in comercially available materials • Im confident that we dont know the volumes but that is not a big concern we assume Volume will grow to a significant level to plan for the future, so again low priority at this point. Since this is a new material it will need to go through the PMN process • This should be fairly easy to track • No good studies	• Analytical Techniques 5(#); 18(%) • Control Technologies 7(#); 25(%) • MWCNT Processing Methods 6(#); 21(%) • MWCNT Purity 5(#); 18(%) • MWCNT Synthesis Methods 5(#); 18(%) • Personal Protective Equipment 5(#); 18(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 14(%) • Aggregation/Agglomeration State 5(#); 18(%) • Applied Coatings 5(#); 18(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 4(#); 14(%) • Charge 5(#); 18(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 3(#); 11(%) • Matrix Bound vs. Free 5(#); 18(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 21(%) • Persistence 3(#); 11(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 5(#); 18(%) • Specific Surface Area 6(#); 21(%) • Structural Formula/Molecular Structure 4(#); 14(%) • Surface Chemistry 6(#); 21(%) • Water Solubility/Dispersibility 6(#); 21(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 5(#); 18(%) • Groundwater 3(#); 11(%) • Sediment 2(#); 7(%) • Soil 3(#); 11(%) • Surface Water 2(#); 7(%) • Wastewater 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 1(#); 4(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 6(#); 21(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 3(#); 11(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 4(#); 14(%) • pH 4(#); 14(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 6(#); 21(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 18(%) • Chronic Exposure 5(#); 18(%) • Exposure Route 4(#); 14(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 1(#); 4(%) • Human Activity 3(#); 11(%) • Individual Activity Level 3(#); 11(%) • Life Stage 2(#); 7(%) • Occupation 2(#); 7(%) • Subchronic Exposure 4(#); 14(%) • Susceptible Populations/Individuals 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
6	Mater a Process ng Release Rate	16(#) 57(%)	11(#) 39(%)	1(#) 4(%)	8(#) 29(%)	7(#) 25(%)	1(#) 4(%)	4(#) 14(%)	5(#) 18(%)	7(#) 25(%)	• F rst Pr nc p es • proportiona to exposure • Here am ntesested n the release to the env ronment. th nk worker exposure s understood and can be mon tored w th N OSH protoco to 7 ug/m3 • ack of pub shed data on quantities manufactured or mported • Release rate (and partic e character stics) s very mportant n estimating potentia for exposure of production workers yet a most no nformation exists espec a y n mass production/ process ng fac ties greatest cha enges are n mon tor ng techn ques • Contro of dust not known exposures expected to be greatest at th s stage • Due to ncrease n permitt ng and safety requ rements for ust about any product these days h gh y un kely that release of the mater a w be a owed at a • ack of release data • Methods and mechan sms exist for hand ng of standard chem ca s such as oxid z ng ac ds and release rates shou d be ab e to be min mized • Same questions exh st as n vo ume but kely contr bution may be better contro ed • No good stud es	• Ana ytica Techn ques 6(#) 21(%) • Contro Techno og es 5(#) 18(%) • MWCNT Process ng Methods 6(#) 21(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 4(#) 14(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 3(#) 11(%) • Aggregation/Agg omeration State 5(#) 18(%) • App ed Coatings 4(#) 14(%) • B odegradab ty 1(#) 4(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 1(#) 4(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 2(#) 7(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 18(%) • Pers stence 4(#) 14(%) • Redox Potentia 1(#) 4(%) • S ze/S ze D str bution 5(#) 18(%) • Spec f c Surface Area 5(#) 18(%) • Structura Formu a/Mo ecu ar Structure 2(#) 7(%) • Surface Chem stry 5(#) 18(%) • Water So ub ty/D spers b ty 6(#) 21(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 11(%) • Groundwater 2(#) 7(%) • Sed ment 2(#) 7(%) • So 2(#) 7(%) • Surface Water 3(#) 11(%) • Wastewater 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 4(%) • L ght Ava ab ty 0(#) 0(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 0(#) 0(%) • W nd 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 1(#) 4(%) • L gand Concentrations n Env ronment 0(#) 0(%) • Natura Organ c Matter (NOM) 1(#) 4(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 2(#) 7(%) • Protein Concentration n Env ronment 0(#) 0(%) • Sa n ty 1(#) 4(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#) 0(%) • B oaccumu ation 3(#) 11(%) • B omagn f cation 0(#) 0(%) • M crob a Commun ties n Env ronment 0(#) 0(%) • Organ sm Hea th 1(#) 4(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 14(%) • Chron c Exposure 4(#) 14(%) • Exposure Route 3(#) 11(%) • Geograph c Location (i.e. rura vs urban) 0(#) 0(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 2(#) 7(%) • L fe Stage 1(#) 4(%) • Occupation 2(#) 7(%) • Subchron c Exposure 3(#) 11(%) • Susceptib e Popu ations/ nd v dua s 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
7	Product Manufactur ng Vo ume	23(#) 82(%)	4(#) 14(%)	1(#) 4(%)	20(#) 71(%)	2(#) 7(%)	1(#) 4(%)	7(#) 25(%)	6(#) 21(%)	10(#) 36(%)	• F rst Pr nc p es • proportiona to exposure • manufacturers shou d be ab e to eas y track production vo umes • Vo ume by any metr c s v ta n order to do any k nd of exposure assessment dur ng manufactur ng whc h aga n s a fundamenta part of r sk assessment • Lack of pub shed data on quantities manufactured or mported • Release scenar os appear to be min ma stud es no mention of the contaminates (i.e. meta cata yst) • There s the potentia for mater a release dur ng manufacture and n partiu ar dur ng the c ean ng processes and app cation of the f ame retardant to textiles The evel of release s kely to be reflected n the sca e of activ ties (as wel as n contro methods used) but there s tt e nformation on th s espec a y as the techno ogy for production s stil develop ng • Uses of MWCNT not wel known wh ch wou d dr ve vo ume Cou d be arge amounts cou d be n che sma amounts • mportant but not cr tica for EE • measurement techn ques can estimate, but on y somewhat conf dent • Need to know s ze of production number of manufacturers • S nce % by weight of CNTs are ow n these mixtures tota vo ume of retardants wou d be necessary to understand potentia exposures • Th s number w continue to grow so t s not worth try ng to co ect data now ust assume t w ncrease to a s gn f cant number can estimate from decaBDE textile use and wt% n textile for worst case • t s not c ear what vo umes of products and correspond ng evel of r sks n manufactur ng w occur • App cation of mater a to fabr c w th spray systems w th potentia for over spray • Lack of centra zed reporting system	• Ana ytica Techn ques 7(#) 25(%) • Contro Techno og es 11(#) 39(%) • MWCNT Process ng Methods 12(#) 43(%) • MWCNT Pur ty 7(#) 25(%) • MWCNT Synthes s Methods 7(#) 25(%) • Persona Protective Equ pment 13(#) 46(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 29(%) • Aggregation/Agg omeration State 10(#) 36(%) • App ed Coatings 10(#) 36(%) • B odegradab ty 3(#) 11(%) • Cata ytic Activ ty 5(#) 18(%) • Charge 8(#) 29(%) • Conductive or Magnetic Properties 4(#) 14(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 11(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 32(%) • Pers stence 7(#) 25(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 11(#) 39(%) • Spec f c Surface Area 9(#) 32(%) • Structura Formu a/Mo ecu ar Structure 5(#) 18(%) • Surface Chem stry 11(#) 39(%) • Water So ub ty/D spers b ty 11(#) 39(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 3(#) 11(%) • Sed ment 2(#) 7(%) • So 4(#) 14(%) • Surface Water 2(#) 7(%) • Wastewater 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 1(#) 4(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 11(%) • D spers ng Agents 9(#) 32(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 0(#) 0(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 18(%) • B oaccumu ation 8(#) 29(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 1(#) 4(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 9(#) 32(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 8(#) 29(%) • Geograph c Location (i.e. rura vs urban) 3(#) 11(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 8(#) 29(%) • nd v dua Activ ty Level 7(#) 25(%) • L fe Stage 2(#) 7(%) • Occupation 9(#) 32(%) • Subchron c Exposure 7(#) 25(%) • Susceptib e Popu ations/ nd v dua s 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
8	Product Manufactur ng Release Rate	23(#) 82(%)	4(#) 14(%)	1(#) 4(%)	19(#) 68(%)	3(#) 11(%)	1(#) 4(%)	7(#) 25(%)	5(#) 18(%)	11(#) 39(%)	• essentia for exposure ana ys s • F rst Pr nc p es • One needs to know the release rate n order to assess the exposure potentia dur ng product manufactur ng • proportiona to exposure • ack of pub shed data on quantities manufactured or mported • mited data • L tt e nformation s ava ab e about how products wou d be manufacturer and how d fferent processes mpact release rates • There s the potentia for mater a release dur ng manufacture and n partiu ar dur ng the celan ng processes and app cation of the f ame retardant to textiles The evel of release s kely to be reflected n the sca e of activ tis (as wel as n contro methods used) but there s tt e nformation on th s espec a y as the techno ogy for production s stil develop ng • Genera methods of app cation of MWCNT formu ations are known and can be used to nform potentia release rates • mportant to estimate exposures • S nce the retardants are most kely to be app ed wet t wou d be necessary to know the potentia for release and exposure • Due to ncrease n permitt ng and safety requ rements for ust about any product these days h gh y un kely that release of the mater a w be a owed at a • Cou d p ay a ro e n ear y release, doesnt seem to matter n ater release stud es • Needs to determined n actua cond tions • ack of centra zed reporting system • No good stud es	• Ana ytica Techn ques 10(#) 36(%) • Contro Techno og es 11(#) 39(%) • MWCNT Process ng Methods 11(#) 39(%) • MWCNT Pur ty 5(#) 18(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 11(#) 39(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 25(%) • Aggregation/Agg omeration State 9(#) 32(%) • App ed Coatings 9(#) 32(%) • B odegradab ty 2(#) 7(%) • Cata ytic Activ ty 3(#) 11(%) • Charge 6(#) 21(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 3(#) 11(%) • Matr x Bound vs Free 12(#) 43(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 10(#) 36(%) • Pers stence 6(#) 21(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 11(#) 39(%) • Spec f c Surface Area 10(#) 36(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 9(#) 32(%) • Water So ub ty/D spers b ty 11(#) 39(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 32(%) • Groundwater 3(#) 11(%) • Sed ment 3(#) 11(%) • So 5(#) 18(%) • Surface Water 4(#) 14(%) • Wastewater 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 4(#) 14(%) • So /Sed ment Fractionation 4(#) 14(%) • Temperature 1(#) 4(%) • W nd 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 8(#) 29(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 3(#) 11(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 1(#) 4(%) • Natura Organ c Matter (NOM) 4(#) 14(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 14(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 2(#) 7(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 1(#) 4(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 8(#) 29(%) • Chron c Exposure 8(#) 29(%) • Exposure Route 7(#) 25(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 6(#) 21(%) • nd v dua Activ ty Level 7(#) 25(%) • L fe Stage 2(#) 7(%) • Occupation 8(#) 29(%) • Subchron c Exposure 6(#) 21(%) • Susceptib e Popu ations/ nd v dua s 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
9	Product Storage, Transport-Volume	2(#); 7(%)	11(#); 39(%)	15(#); 54(%)	2(#); 7(%)	0(#); 0(%)	0(#); 0(%)	2(#); 7(%)	0(#); 0(%)	0(#); 0(%)	• Need to estimate exposures • proportional to exposure	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
10	Product Storage, Transport-Release Rate	2(#); 7(%)	11(#); 39(%)	15(#); 54(%)	2(#); 7(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)	• proportional to exposure • Similar to other chemicals	• Analytical Techniques 1(#); 4(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
11	Use-Vo ume	20(#) 71(%)	8(#) 29(%)	0(#) 0(%)	17(#) 61(%)	2(#) 7(%)	1(#) 4(%)	5(#) 18(%)	5(#) 18(%)	10(#) 36(%)	• essentia for exposure ana ys s • Need to estimate exposures • proportiona to exposure • App cations not defined or known so no way of know ng f vo ume w be b g or sma • nformation s genera y not supp ed by the manufacturers about numbers of products and MWCNT concentrations n products • ack of pub shed data on quantities manufactured or mported • mited data • Vo ume used s key n order to comp ete exposure assessments dur ng uses At the moment, we do either not have the nformation about uses and vo ume or we do not have access to such nformation • Current f ame retardant coating exposure w th upho stery use s somewhat known R sk w th use of MWCNT product s not known • can estimate worst case as current decaBDE textiles • The da y use wou d cause release of partic es and accumu ation n house dust • Market pred ctions for the s ze of the MWCNT market vary by orders of magn tude and w kely change further as we get more fami ar w th the techno ogy	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 6(#) 21(%) • MWCNT Process ng Methods 7(#) 25(%) • MWCNT Pur ty 6(#) 21(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 3(#) 11(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 32(%) • Aggregation/Agg omeration State 9(#) 32(%) • App ed Coatings 10(#) 36(%) • B odegradab ty 5(#) 18(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 6(#) 21(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 10(#) 36(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 8(#) 29(%) • Redox Potentia 3(#) 11(%) • S ze/S ze D str bution 10(#) 36(%) • Spec f c Surface Area 7(#) 25(%) • Structura Formu a/Mo ecu ar Structure 5(#) 18(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 8(#) 29(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 8(#) 29(%) • Groundwater 2(#) 7(%) • Sed ment 3(#) 11(%) • So 5(#) 18(%) • Surface Water 2(#) 7(%) • Wastewater 7(#) 25(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 1(#) 4(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 1(#) 4(%) • Natura Organ c Matter (NOM) 2(#) 7(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 21(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 6(#) 21(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 21(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 8(#) 29(%) • Geograph c Location (i.e. rura vs urban) 4(#) 14(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 8(#) 29(%) • nd v dua Activ ty Level 9(#) 32(%) • L fe Stage 4(#) 14(%) • Occupation 6(#) 21(%) • Subchron c Exposure 8(#) 29(%) • Susceptib e Popu ations/ nd v dua s 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
12	Use-Release Rate	20(#) 71(%)	8(#) 29(%)	0(#) 0(%)	18(#) 64(%)	2(#) 7(%)	0(#) 0(%)	2(#) 7(%)	2(#) 7(%)	16(#) 57(%)	• essentia for exposure ana ys s • proportiona to exposure • App cations not defined or known so no way of know ng f use of the product (wh ch wou d determine release rate) w or w not release MWCNT • As n the case of product manufactur ng release rate s v ta n order to comp ete an exposure assessment dur ng uses • nformation on decaBDE release dur ng the use phase of a f ame retardent suggests that there s a cons derab e potentia for CNT release f used n a s mi ar manner (e.g textiles). The evel of release and phys cochem ca character stics of the released partic es therefore s of utmost concern espec a y as wh st contro measures are common y used dur ng synthes s process ng and manfactur ng phases they are not typ ca y used by consumers • ack of pub shed data on quantities manufactured or mported • The rate of release of MWCNTs and assoc ated hazards from new to be made products s not wel known mostly because the exact mater a s formu ations processes products and use scenar os are to be determined • There are few stud es on release rates from products or po ymer nanocompos tes w th MWCNTs • We earned from PDBEs that even though t was thought there wou d be no release there ends up being a release. Th s must be understood • S mi ar to other chem ca s • Not enough data or test methods	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 8(#) 29(%) • MWCNT Process ng Methods 10(#) 36(%) • MWCNT Pur ty 9(#) 32(%) • MWCNT Synthes s Methods 8(#) 29(%) • Persona Protective Equ pment 4(#) 14(%) • Other 3(#) 11(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 43(%) • Aggregation/Agg omeration State 13(#) 46(%) • App ed Coatings 14(#) 50(%) • B odegradab ty 5(#) 18(%) • Cata ytic Activ ty 5(#) 18(%) • Charge 7(#) 25(%) • Conductive or Magnetic Properties 4(#) 14(%) • Crysta ne Phase 3(#) 11(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 15(#) 54(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 12(#) 43(%) • Pers stence 9(#) 32(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 14(#) 50(%) • Spec f c Surface Area 10(#) 36(%) • Structura Formu a/Mo ecu ar Structure 7(#) 25(%) • Surface Chem stry 11(#) 39(%) • Water So ub ty/D spers b ty 12(#) 43(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 4(#) 14(%) • Sed ment 5(#) 18(%) • So 7(#) 25(%) • Surface Water 3(#) 11(%) • Wastewater 8(#) 29(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 3(#) 11(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 2(#) 7(%) • W nd 4(#) 14(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 7(#) 25(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 21(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 5(#) 18(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 8(#) 29(%) • Chron c Exposure 11(#) 39(%) • Exposure Route 10(#) 36(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 4(#) 14(%) • Human Activ ty 11(#) 39(%) • nd v dua Activ ty Level 12(#) 43(%) • L fe Stage 6(#) 21(%) • Occupation 8(#) 29(%) • Subchron c Exposure 10(#) 36(%) • Susceptib e Popu ations/ nd v dua s 11(#) 39(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)
13	D sposa /Recyc ng Vo ume	17(#) 61(%)	9(#) 32(%)	2(#) 7(%)	13(#) 46(%)	4(#) 14(%)	0(#) 0(%)	6(#) 21(%)	4(#) 14(%)	7(#) 25(%)	• essentia for exposure ana ys s • Need to estimate exposures • proportiona to exposure • App cations not defined or known nor f the products cou d be recyc ed or how they can be d sposed of • products are too mmature for suff c ent data • There s an nformation gap on the k ey future evel of recyc ng as t s gradua y becoming ess commerc a y and soc a y acceptab e to produce mater a s wh ch cannot be recyc ed Therefore the compar son w th decaBDE based f ame retardent mater a s may ead to an under estimation of the vo ume of recovery and recyc ng of NT conta n ng f ame retardants • Th s depends on the magn tude of products d sposed of or recyc ed • Vo ume d sposed and recyc ed s v ta n order to assess exposure over time and the mon tor trends • Current f ame retardant coating exposure w th upho stery use s somewhat known R sk w th use of MWCNT product s not known • We are aware of what vo umes of textiles that are d sposed/recyc ed • Market pred ctions for u timate vo ume vary th s s further compounded by unknown end of fe deta s	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 6(#) 21(%) • MWCNT Process ng Methods 5(#) 18(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 6(#) 21(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 3(#) 11(%) • Cata ytic Activ ty 1(#) 4(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 1(#) 4(%) • Crysta ne Phase 0(#) 0(%) • L poph c ty 4(#) 14(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 18(%) • Pers stence 5(#) 18(%) • Redox Potentia 1(#) 4(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 4(#) 14(%) • Water So ub ty/D spers b ty 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 4(#) 14(%) • Groundwater 4(#) 14(%) • Sed ment 4(#) 14(%) • So 4(#) 14(%) • Surface Water 3(#) 11(%) • Wastewater 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 2(#) 7(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 2(#) 7(%) • L gand Concentrations n Env ronment 1(#) 4(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 2(#) 7(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 1(#) 4(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 4(#) 14(%) • B omagn f cation 2(#) 7(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 14(%) • Chron c Exposure 4(#) 14(%) • Exposure Route 4(#) 14(%) • Geograph c Location (i.e. rura vs urban) 3(#) 11(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 2(#) 7(%) • L fe Stage 2(#) 7(%) • Occupation 3(#) 11(%) • Subchron c Exposure 3(#) 11(%) • Susceptib e Popu ations/ nd v dua s 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
14	D sposa /Recyc ng Release Rate	17(#) 61(%)	9(#) 32(%)	2(#) 7(%)	13(#) 46(%)	4(#) 14(%)	0(#) 0(%)	3(#) 11(%)	4(#) 14(%)	10(#) 36(%)	• essentia for exposure ana ys s • proportiona to exposure • Lack of data or ana ogue data • L tt e data ava ab e s nce arge sca e manufactur ng of CNT coated textiles has not occurred No opportun ties to conduct stud es s nce mater a s are not be d sposed of yet. • Release rates dur ng d sposa and recyc ng processes need to be known n order to assess exposure • Same ssue for vo ume app cations not defined recyc e methods unknown and f na fate of sa d product conta n ng MWCNT unknown rea ze the study s supposed to focus on MWCNT for use n textile backcoatings but s nce there s no proof that th s w ever actua y be used one cannot ust assume releases from furn ture go ng to andf s a correct model • The nature of release from mater a s dur ng recyc ng may be of concern particu ar y dur ng processess such as shred ng yet tt e nformation exits on the nature of the released mater a ts rate of release nor the contro measures used to mit exposure. n add tion the rate of release dur ng decompos tion n and f (and subsquent d str bution nto ground water etc) s of nterest. • Th s w determine the mpact of the vo ume of MWCNT conta n ng products and where MWCNTs are released (dur ng recyc ng n andf s etc) • Unknown release rate/mechan sm for MWCNT f ame retardant upho stery coatings • Non nc nerator d sposa needs more character zation • The release rate w vary based on spec f c formu ation deta s th s s further compounded by unknown end of fe deta s	• Ana ytica Techn ques 8(#) 29(%) • Contro Techno og es 8(#) 29(%) • MWCNT Process ng Methods 6(#) 21(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 25(%) • Aggregation/Agg omeration State 9(#) 32(%) • App ed Coatings 6(#) 21(%) • B odegradab ty 7(#) 25(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 6(#) 21(%) • Conductive or Magnetic Properties 1(#) 4(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 9(#) 32(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 7(#) 25(%) • Redox Potentia 1(#) 4(%) • S ze/S ze D str bution 7(#) 25(%) • Spec f c Surface Area 6(#) 21(%) • Structura Formu a/Mo ecu ar Structure 5(#) 18(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 9(#) 32(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 9(#) 32(%) • Groundwater 6(#) 21(%) • Sed ment 7(#) 25(%) • So 9(#) 32(%) • Surface Water 5(#) 18(%) • Wastewater 7(#) 25(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 5(#) 18(%) • So /Sed ment Fractionation 6(#) 21(%) • Temperature 3(#) 11(%) • W nd 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 6(#) 21(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 5(#) 18(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 5(#) 18(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 18(%) • Chron c Exposure 5(#) 18(%) • Exposure Route 4(#) 14(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 4(#) 14(%) • nd v dua Activ ty Level 4(#) 14(%) • L fe Stage 3(#) 11(%) • Occupation 5(#) 18(%) • Subchron c Exposure 3(#) 11(%) • Susceptib e Popu ations/ nd v dua s 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
15	A r Mob ty	27(#) 96(%)	1(#) 4(%)	0(#) 0(%)	23(#) 82(%)	3(#) 11(%)	1(#) 4(%)	4(#) 14(%)	6(#) 21(%)	17(#) 61(%)	• abundant data • aer a d spers on s a concern ack of d spers on nformation • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • Dependent on cond tions of what happens to tubes once a rborne or settled/red sturbed • L tt e nformation on a rborne env ronmenta fate once t s released Most kely scenar o for exposure. • Mob ty vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known need to understand for ndoor use once t s released from textiles to estimate dust evels • No stud es have descr bed transport of CNTs n a r no rea stic stud es • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • There seems mited nformation on the effect of partic e character stics as wel as env ronmenta factors on the mob ty of CNT n the a r very tt e data on th s front; d ff cu t to des gn contro ed exper ments • Much of what we know about other organ c aeroso s may be relevant • On y ava ab e data on a r mob ty s from mited occupationa exposure stud es • Shou d rema n on dust • No data on CNT release to a r or what happens when they are released • f the partic e s ze s known can pred ct motion • n TTF category nha ation wou d be the ma or route of exposure. Yet most ava ab e data are from the stud es conducted n ess rea stic cond tions	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 9(#) 32(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 8(#) 29(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 8(#) 29(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 11(#) 39(%) • Aggregation/Agg omeration State 17(#) 61(%) • App ed Coatings 10(#) 36(%) • B odegradab ty 7(#) 25(%) • Cata ytic Activ ty 7(#) 25(%) • Charge 11(#) 39(%) • Conductive or Magnetic Properties 5(#) 18(%) • Crysta ne Phase 4(#) 14(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 16(#) 57(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 12(#) 43(%) • Pers stence 9(#) 32(%) • Redox Potentia 7(#) 25(%) • S ze/S ze D str bution 16(#) 57(%) • Spec f c Surface Area 12(#) 43(%) • Structura Formu a/Mo ecu ar Structure 8(#) 29(%) • Surface Chem stry 12(#) 43(%) • Water So ub ty/D spers b ty 9(#) 32(%) • Other 3(#) 11(%) • Spec fy other 0(#) 0(%)	• A r 13(#) 46(%) • Groundwater 2(#) 7(%) • Sed ment 3(#) 11(%) • So 4(#) 14(%) • Surface Water 4(#) 14(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 8(#) 29(%) • L ght Ava ab ty 3(#) 11(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 8(#) 29(%) • W nd 14(#) 50(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 11(%) • D spers ng Agents 9(#) 32(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 5(#) 18(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 5(#) 18(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 5(#) 18(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 4(#) 14(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 25(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 8(#) 29(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 4(#) 14(%) • Human Activ ty 9(#) 32(%) • nd v dua Activ ty Level 6(#) 21(%) • L fe Stage 5(#) 18(%) • Occupation 4(#) 14(%) • Subchron c Exposure 8(#) 29(%) • Susceptib e Popu ations/ nd v dua s 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
16	A r Pers stence	27(#) 96(%)	1(#) 4(%)	0(#) 0(%)	15(#) 54(%)	10(#) 36(%)	2(#) 7(%)	7(#) 25(%)	4(#) 14(%)	16(#) 57(%)	• abundant data • nsuff c ent data • aer a d spers on s a concern potentia for photoactivation/degredation/etc • We know that MWCNT are very pers stent • Accumu ation n areas wou d be s gn f cant. • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • mportant to estimate potentia dose • L tt e nformation appears to be ava ab e • Need to define pers stence (e.g b opers stence, env ronmenta). An ma stud es nd cate b opers stence of MWCNT • mited pers stence n a r s expected outdoors w go to so or water f released to a r • No stud es have descr bed pers stence n a r • Pers stance vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known • No data on CNT release to a r or what happens when they are released • Bu d up • Shou d not pers st n a r for very ong mater a w settle • depends on depos tion • MWCNTS are probab y ess pers stant than a ot of other ndustr a chem ca s (i.e. ess thermodynamica y stab e). • No rea stic stud es	• Ana ytica Techn ques 10(#) 36(%) • Contro Techno og es 8(#) 29(%) • MWCNT Process ng Methods 7(#) 25(%) • MWCNT Pur ty 8(#) 29(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 6(#) 21(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 36(%) • Aggregation/Agg omeration State 13(#) 46(%) • App ed Coatings 9(#) 32(%) • B odegradab ty 10(#) 36(%) • Cata ytic Activ ty 6(#) 21(%) • Charge 9(#) 32(%) • Conductive or Magnetic Properties 4(#) 14(%) • Crysta ne Phase 4(#) 14(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 13(#) 46(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 11(#) 39(%) • Pers stence 12(#) 43(%) • Redox Potentia 6(#) 21(%) • S ze/S ze D str bution 10(#) 36(%) • Spec f c Surface Area 8(#) 29(%) • Structura Formu a/Mo ecu ar Structure 7(#) 25(%) • Surface Chem stry 9(#) 32(%) • Water So ub ty/D spers b ty 7(#) 25(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 1(#) 4(%) • Sed ment 2(#) 7(%) • So 4(#) 14(%) • Surface Water 4(#) 14(%) • Wastewater 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 6(#) 21(%) • L ght Ava ab ty 4(#) 14(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 5(#) 18(%) • W nd 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 3(#) 11(%) • D spers ng Agents 7(#) 25(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 3(#) 11(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 2(#) 7(%) • Other Contaminants n Env ronment 5(#) 18(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 1(#) 4(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 14(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 5(#) 18(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 18(%) • Chron c Exposure 5(#) 18(%) • Exposure Route 4(#) 14(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 4(#) 14(%) • Human Activ ty 6(#) 21(%) • nd v dua Activ ty Level 6(#) 21(%) • L fe Stage 5(#) 18(%) • Occupation 4(#) 14(%) • Subchron c Exposure 6(#) 21(%) • Susceptib e Popu ations/ nd v dua s 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
17	A r B oava ab ty	27(#) 96(%)	1(#) 4(%)	0(#) 0(%)	18(#) 64(%)	6(#) 21(%)	3(#) 11(%)	4(#) 14(%)	5(#) 18(%)	18(#) 64(%)	• abundant data • nsuff c ent data • aer a d spers on s a concern potentia exposure to a r breath ng organ sms h gh • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • B oava ab ty vs MWCNT form and formu ation data for MWCNT f ame retardant upho stery coatings are not wel known • Chem ca transformations of a r borne nanotubes may a ter their b oava ab ty • most nha ab e s ze fraction and and agg omeration vs s ng e f ber fate • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • On y based on other particu ate types • No data on CNT release to a r or what happens when they are released • Shou d rema n on dust, exposure by nha ation • Ava ab ty n comb nation w th other exposures cou d be s gn f cant. • Lack of pub shed data • Not a concern for env ronment and f res dence time n a r (mob ty) s short enough t w reduce human nha ation exposure. What s ze are partic es as nha ed nto ung f aggregation occurs cou d reduce b oava ab ty v a nha ation • B oava ab ty nformation s ava ab e for other med a • Depends on ocation of depos t • No rea stic stud es	• Ana ytica Techn ques 11(#) 39(%) • Contro Techno og es 6(#) 21(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 10(#) 36(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 8(#) 29(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 13(#) 46(%) • Aggregation/Agg omeration State 15(#) 54(%) • App ed Coatings 13(#) 46(%) • B odegradab ty 11(#) 39(%) • Cata ytic Activ ty 7(#) 25(%) • Charge 10(#) 36(%) • Conductive or Magnetic Properties 4(#) 14(%) • Crysta ne Phase 5(#) 18(%) • L poph c ty 11(#) 39(%) • Matr x Bound vs Free 13(#) 46(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 12(#) 43(%) • Pers stence 11(#) 39(%) • Redox Potentia 9(#) 32(%) • S ze/S ze D str bution 12(#) 43(%) • Spec f c Surface Area 11(#) 39(%) • Structura Formu a/Mo ecu ar Structure 8(#) 29(%) • Surface Chem stry 13(#) 46(%) • Water So ub ty/D spers b ty 11(#) 39(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 3(#) 11(%) • Sed ment 4(#) 14(%) • So 5(#) 18(%) • Surface Water 5(#) 18(%) • Wastewater 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 5(#) 18(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 4(#) 14(%) • W nd 10(#) 36(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 8(#) 29(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 4(#) 14(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 4(#) 14(%) • Natura Organ c Matter (NOM) 4(#) 14(%) • Other Contaminants n Env ronment 5(#) 18(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 3(#) 11(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 7(#) 25(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 21(%) • B oaccumu ation 9(#) 32(%) • B omagn f cation 6(#) 21(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 7(#) 25(%) • Spec es/ nd v dua Developmenta Behav or 5(#) 18(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 21(%) • Spec es/ nd v dua Reproductive Behav or 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 21(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 8(#) 29(%) • Geograph c Location (i.e. rura vs urban) 6(#) 21(%) • Hab tat Structure 4(#) 14(%) • Human Activ ty 9(#) 32(%) • nd v dua Activ ty Level 7(#) 25(%) • L fe Stage 6(#) 21(%) • Occupation 5(#) 18(%) • Subchron c Exposure 7(#) 25(%) • Susceptib e Popu ations/ nd v dua s 9(#) 32(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
18	Surface Water-Mobility	12(#); 43(%)	13(#); 46(%)	3(#); 11(%)	11(#); 39(%)	1(#); 4(%)	0(#); 0(%)	3(#); 11(%)	4(#); 14(%)	5(#); 18(%)	• SW may be major distribution route • this can be tested more directly • Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • Our knowledge about the mobility of MWCNT is very limited and why do not know whether the test methods we use to assess mobility of regular chemical are approrpiate • There are a number of papers on this topic but the full range of contexts has not been adequately studied nor are models validated • Insufficient data	• Analytical Techniques 4(#); 14(%) • Control Technologies 4(#); 14(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 5(#); 18(%) • MWCNT Synthesis Methods 3(#); 11(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 7(#); 25(%) • Aggregation/Agglomeration State 7(#); 25(%) • Applied Coatings 7(#); 25(%) • Biodegradability 6(#); 21(%) • Catalytic Activity 4(#); 14(%) • Charge 4(#); 14(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 7(#); 25(%) • Matrix Bound vs. Free 6(#); 21(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 21(%) • Persistence 2(#); 7(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 7(#); 25(%) • Specific Surface Area 6(#); 21(%) • Structural Formula/Molecular Structure 5(#); 18(%) • Surface Chemistry 6(#); 21(%) • Water Solubility/Dispersibility 6(#); 21(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 3(#); 11(%) • Groundwater 2(#); 7(%) • Sediment 4(#); 14(%) • Soil 4(#); 14(%) • Surface Water 6(#); 21(%) • Wastewater 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 6(#); 21(%) • Light Availability 2(#); 7(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 4(#); 14(%) • Temperature 5(#); 18(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 4(#); 14(%) • Dispersing Agents 7(#); 25(%) • Dissolved Oxygen Content 4(#); 14(%) • Exposure to Sunlight 4(#); 14(%) • Heavy Metals in Environment 6(#); 21(%) • Ionic Strength in Environment 8(#); 29(%) • Ligand Concentrations in Environment 7(#); 25(%) • Natural Organic Matter (NOM) 8(#); 29(%) • Other Contaminants in Environment 6(#); 21(%) • pH 6(#); 21(%) • Protein Concentration in Environment 5(#); 18(%) • Salinity 8(#); 29(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 11(%) • Bioaccumulation 4(#); 14(%) • Biomagnification 3(#); 11(%) • Microbial Communities in Environment 4(#); 14(%) • Organism Health 3(#); 11(%) • Species/Individual Developmental Behavior 2(#); 7(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 4(#); 14(%) • Exposure Route 4(#); 14(%) • Geographic Location (i.e. rural vs. urban) 4(#); 14(%) • Habitat Structure 2(#); 7(%) • Human Activity 6(#); 21(%) • Individual Activity Level 3(#); 11(%) • Life Stage 2(#); 7(%) • Occupation 2(#); 7(%) • Subchronic Exposure 3(#); 11(%) • Susceptible Populations/Individuals 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
19	Surface Water-Persistence	12(#); 43(%)	13(#); 46(%)	3(#); 11(%)	10(#); 36(%)	2(#); 7(%)	0(#); 0(%)	3(#); 11(%)	4(#); 14(%)	5(#); 18(%)	• SW may be major distribution route • We know that MWCNT are very persistent • MWCNTS are probably less persistant than a lot of other industrial chemicals (i.e., less thermodynamically stable). • Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • Few studies are available on this topic but MWCNTs are expected to be fairly resistant to degradation • Insufficient data	• Analytical Techniques 4(#); 14(%) • Control Technologies 3(#); 11(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 18(%) • Aggregation/Agglomeration State 6(#); 21(%) • Applied Coatings 5(#); 18(%) • Biodegradability 5(#); 18(%) • Catalytic Activity 3(#); 11(%) • Charge 3(#); 11(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 6(#); 21(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 14(%) • Persistence 6(#); 21(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 5(#); 18(%) • Specific Surface Area 4(#); 14(%) • Structural Formula/Molecular Structure 5(#); 18(%) • Surface Chemistry 5(#); 18(%) • Water Solubility/Dispersibility 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 3(#); 11(%) • Sediment 4(#); 14(%) • Soil 5(#); 18(%) • Surface Water 6(#); 21(%) • Wastewater 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 4(#); 14(%) • Light Availability 2(#); 7(%) • Soil Porosity 3(#); 11(%) • Soil/Sediment Fractionation 5(#); 18(%) • Temperature 4(#); 14(%) • Wind 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 4(#); 14(%) • Dispersing Agents 5(#); 18(%) • Dissolved Oxygen Content 3(#); 11(%) • Exposure to Sunlight 3(#); 11(%) • Heavy Metals in Environment 5(#); 18(%) • Ionic Strength in Environment 6(#); 21(%) • Ligand Concentrations in Environment 5(#); 18(%) • Natural Organic Matter (NOM) 6(#); 21(%) • Other Contaminants in Environment 5(#); 18(%) • pH 5(#); 18(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 5(#); 18(%) • Surfactant (in Lab) 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 7(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 3(#); 11(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 4(#); 14(%) • Exposure Route 3(#); 11(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 1(#); 4(%) • Human Activity 4(#); 14(%) • Individual Activity Level 3(#); 11(%) • Life Stage 2(#); 7(%) • Occupation 2(#); 7(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
20	Surface Water-Bioavailability	12(#); 43(%)	13(#); 46(%)	3(#); 11(%)	9(#); 32(%)	3(#); 11(%)	0(#); 0(%)	2(#); 7(%)	3(#); 11(%)	7(#); 25(%)	• SW may be major distribution route; potential uptake, accumulation, and foodchain transfer in aquatic organisms; including plants. • Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • Our knowledge about the bioavailability of MWCNT is very limited and why do not know whether the test methods we use to assess bioavailability of regular chemical are approrpiate • Probably not so bioavailable (maybe metal impurities are relevant), but good chance of contact with organisms of concern. • There is relatively sparse data on this due to complicated nature of quantifying nanotubes in biological matrices • Ingestion by organisms will likely impact transport and also is likely to increase agglomeration and settling out of solution • Insufficient data	• Analytical Techniques 5(#); 18(%) • Control Technologies 4(#); 14(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 4(#); 14(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 21(%) • Aggregation/Agglomeration State 7(#); 25(%) • Applied Coatings 6(#); 21(%) • Biodegradability 6(#); 21(%) • Catalytic Activity 3(#); 11(%) • Charge 4(#); 14(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 8(#); 29(%) • Matrix Bound vs. Free 7(#); 25(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 21(%) • Persistence 4(#); 14(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 7(#); 25(%) • Specific Surface Area 5(#); 18(%) • Structural Formula/Molecular Structure 4(#); 14(%) • Surface Chemistry 7(#); 25(%) • Water Solubility/Dispersibility 5(#); 18(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 2(#); 7(%) • Groundwater 3(#); 11(%) • Sediment 3(#); 11(%) • Soil 4(#); 14(%) • Surface Water 5(#); 18(%) • Wastewater 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 4(#); 14(%) • Light Availability 1(#); 4(%) • Soil Porosity 3(#); 11(%) • Soil/Sediment Fractionation 5(#); 18(%) • Temperature 3(#); 11(%) • Wind 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 4(#); 14(%) • Dispersing Agents 6(#); 21(%) • Dissolved Oxygen Content 4(#); 14(%) • Exposure to Sunlight 3(#); 11(%) • Heavy Metals in Environment 6(#); 21(%) • Ionic Strength in Environment 7(#); 25(%) • Ligand Concentrations in Environment 6(#); 21(%) • Natural Organic Matter (NOM) 8(#); 29(%) • Other Contaminants in Environment 6(#); 21(%) • pH 7(#); 25(%) • Protein Concentration in Environment 5(#); 18(%) • Salinity 8(#); 29(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 11(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 3(#); 11(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 4(#); 14(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 4(#); 14(%) • Exposure Route 3(#); 11(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 1(#); 4(%) • Human Activity 5(#); 18(%) • Individual Activity Level 3(#); 11(%) • Life Stage 3(#); 11(%) • Occupation 2(#); 7(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
21	Groundwater-Mobility	4(#); 14(%)	11(#); 39(%)	13(#); 46(%)	3(#); 11(%)	1(#); 4(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	3(#); 11(%)	• Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • lack of repeatability in data
22	Groundwater-Persistence	4(#); 14(%)	11(#); 39(%)	13(#); 46(%)	2(#); 7(%)	2(#); 7(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	3(#); 11(%)	• Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • MWCNTS are probably less persistant than a lot of other industrial chemicals (i.e., less thermodynamically stable).
23	Groundwater-Bioavailability	4(#); 14(%)	11(#); 39(%)	13(#); 46(%)	2(#); 7(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)	1(#); 4(%)	3(#); 11(%)	• Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • Fewer organisms of concern in the aquifer; probably not so bioavailable.

ID	Element-RRF Pair	Influential Factors						
		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
21	Groundwater-Mobility	• Analytical Techniques 1(#); 4(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 11(%) • Aggregation/Agglomeration State 3(#); 11(%) • Applied Coatings 3(#); 11(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 2(#); 7(%) • Charge 3(#); 11(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 3(#); 11(%) • Matrix Bound vs. Free 3(#); 11(%) • Morphology (e.g. aspect ratio, length, width, shape) 3(#); 11(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 3(#); 11(%) • Specific Surface Area 3(#); 11(%) • Structural Formula/Molecular Structure 3(#); 11(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 2(#); 7(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 3(#); 11(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 3(#); 11(%) • Ionic Strength in Environment 3(#); 11(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 3(#); 11(%) • Other Contaminants in Environment 3(#); 11(%) • pH 2(#); 7(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 3(#); 11(%) • Surfactant (in Lab) 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 7(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 2(#); 7(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 3(#); 11(%) • Exposure Route 2(#); 7(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 2(#); 7(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 1(#); 4(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
22	Groundwater-Persistence	• Analytical Techniques 1(#); 4(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 2(#); 7(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 1(#); 4(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 1(#); 4(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 2(#); 7(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 2(#); 7(%) • pH 2(#); 7(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 1(#); 4(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 1(#); 4(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
23	Groundwater-Bioavailability	• Analytical Techniques 1(#); 4(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 2(#); 7(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 1(#); 4(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 1(#); 4(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 2(#); 7(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 2(#); 7(%) • pH 2(#); 7(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 1(#); 4(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 1(#); 4(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
24	Wastewater Mob ty	19(#) 68(%)	7(#) 25(%)	2(#) 7(%)	18(#) 64(%)	1(#) 4(%)	0(#) 0(%)	3(#) 11(%)	6(#) 21(%)	10(#) 36(%)	• antic pated ma or source of MWNT • can be repeatab y tested • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • Data not ava ab e on mob ty of MWCNTs n wastewater • Much of th s data s mited by the need for more robust methods for quantitation of MWNTs n wastewater • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • Where does t end up? • Few stud es descr be MWCNT remova by wastewater treatment processes • kely to accumu ate n wastewater s mater a co ected from eff uent? • poss b e ma or route of env ronmenta release; cou d be modeled from f rst pr nc pa • Wh st there may not be agreat dea of data on the mob ty of CNT n WWTP we do know they tend to agg omerate rap d y and ev dence from other NPs (e.g T O2) suggests reduced mob ty and rap d sed mentation nto the s udge • Shou d be determined by s ze	• Ana ytica Techn ques 11(#) 39(%) • Contro Techno og es 6(#) 21(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 5(#) 18(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 43(%) • Aggregation/Agg omeration State 13(#) 46(%) • App ed Coatings 9(#) 32(%) • B odegradab ty 10(#) 36(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 5(#) 18(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 10(#) 36(%) • Matr x Bound vs Free 13(#) 46(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 9(#) 32(%) • Pers stence 5(#) 18(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 8(#) 29(%) • Spec f c Surface Area 6(#) 21(%) • Structura Formu a/Mo ecu ar Structure 6(#) 21(%) • Surface Chem stry 12(#) 43(%) • Water So ub ty/D spers b ty 12(#) 43(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 3(#) 11(%) • Sed ment 3(#) 11(%) • So 5(#) 18(%) • Surface Water 3(#) 11(%) • Wastewater 11(#) 39(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 9(#) 32(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 6(#) 21(%) • Temperature 4(#) 14(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 5(#) 18(%) • D spers ng Agents 9(#) 32(%) • D sso ved Oxygen Content 5(#) 18(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 7(#) 25(%) • on c Strength n Env ronment 9(#) 32(%) • L gand Concentrations n Env ronment 8(#) 29(%) • Natura Organ c Matter (NOM) 11(#) 39(%) • Other Contaminants n Env ronment 7(#) 25(%) • pH 8(#) 29(%) • Protein Concentration n Env ronment 6(#) 21(%) • Sa n ty 7(#) 25(%) • Surfactant (in Lab) 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 3(#) 11(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 6(#) 21(%) • Organ sm Hea th 4(#) 14(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 14(%) • Chron c Exposure 4(#) 14(%) • Exposure Route 3(#) 11(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 2(#) 7(%) • Human Activ ty 5(#) 18(%) • nd v dua Activ ty Level 1(#) 4(%) • L fe Stage 1(#) 4(%) • Occupation 2(#) 7(%) • Subchron c Exposure 4(#) 14(%) • Susceptib e Popu ations/ nd v dua s 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
25	Wastewater Pers stence	19(#) 68(%)	7(#) 25(%)	2(#) 7(%)	17(#) 61(%)	2(#) 7(%)	0(#) 0(%)	4(#) 14(%)	5(#) 18(%)	10(#) 36(%)	• Comp ex b o og ca med a w th mu tip epotentia b o og ca /phys ca routes of transformation • We know that MWCNT are very pers stent • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • Data not ava ab e on pers stence of MWCNTs n wastewater • L fetime n env ronment mpt • most kely not pers stent n wastewater • CNT have been shown n other b o og ca systems to be rather pers stant so wh st not spec fc data t s nd cative. • Cou d be der ved from chem ca pr n c pa s • t s un kely for substantia degradation to occur based on the short time n wastewater treatment p ants • The Zhu et a (2011) paper on MWCNT oxidation needs to ver f ed to determine fe time of mater a	• Ana ytica Techn ques 8(#) 29(%) • Contro Techno og es 4(#) 14(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 9(#) 32(%) • Aggregation/Agg omeration State 9(#) 32(%) • App ed Coatings 7(#) 25(%) • B odegradab ty 9(#) 32(%) • Cata ytic Activ ty 5(#) 18(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 7(#) 25(%) • Matr x Bound vs Free 10(#) 36(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 18(%) • Pers stence 9(#) 32(%) • Redox Potentia 5(#) 18(%) • S ze/S ze D str bution 5(#) 18(%) • Spec f c Surface Area 4(#) 14(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 8(#) 29(%) • Water So ub ty/D spers b ty 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 3(#) 11(%) • Sed ment 3(#) 11(%) • So 4(#) 14(%) • Surface Water 3(#) 11(%) • Wastewater 9(#) 32(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 6(#) 21(%) • L ght Ava ab ty 3(#) 11(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 6(#) 21(%) • Temperature 5(#) 18(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 5(#) 18(%) • D spers ng Agents 6(#) 21(%) • D sso ved Oxygen Content 4(#) 14(%) • Exposure to Sun ght 4(#) 14(%) • Heavy Meta s n Env ronment 5(#) 18(%) • on c Strength n Env ronment 7(#) 25(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 9(#) 32(%) • Other Contaminants n Env ronment 6(#) 21(%) • pH 6(#) 21(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 3(#) 11(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 3(#) 11(%) • Chron c Exposure 2(#) 7(%) • Exposure Route 2(#) 7(%) • Geograph c Location (i.e. rura vs urban) 4(#) 14(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 1(#) 4(%) • Occupation 1(#) 4(%) • Subchron c Exposure 3(#) 11(%) • Susceptib e Popu ations/ nd v dua s 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
26	Wastewater B oava ab ty	19(#) 68(%)	7(#) 25(%)	2(#) 7(%)	11(#) 39(%)	8(#) 29(%)	0(#) 0(%)	2(#) 7(%)	3(#) 11(%)	14(#) 50(%)	• M crobes and microb a b of ms must mportant and probab e organ sms of concern n WWTP • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • L tt e data ava ab e on b oava ab ty of MWCNT forms for f ame retardants n wastewater • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • The degree of b oava ab ty espec a y post treament (eff uent and s udge) and partic e character stics are not wel d scr bed but are of mportance n understand ng b o nteractions • some data ava ab e • nteractions w th activated s udge and microorgan sms w kely mpact the remova rates before release nto water systems a though nteractions w th s udge can ead to and app cation • most kely b oava ab e to benth c organ sms • t may be trapped n the so d phase	• Ana ytica Techn ques 8(#) 29(%) • Contro Techno og es 5(#) 18(%) • MWCNT Process ng Methods 4(#) 14(%) • MWCNT Pur ty 5(#) 18(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 43(%) • Aggregation/Agg omeration State 11(#) 39(%) • App ed Coatings 8(#) 29(%) • B odegradab ty 10(#) 36(%) • Cata ytic Activ ty 3(#) 11(%) • Charge 5(#) 18(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 10(#) 36(%) • Matr x Bound vs Free 12(#) 43(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 7(#) 25(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 8(#) 29(%) • Spec f c Surface Area 7(#) 25(%) • Structura Formu a/Mo ecu ar Structure 6(#) 21(%) • Surface Chem stry 11(#) 39(%) • Water So ub ty/D spers b ty 10(#) 36(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 3(#) 11(%) • Sed ment 3(#) 11(%) • So 5(#) 18(%) • Surface Water 4(#) 14(%) • Wastewater 10(#) 36(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 6(#) 21(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 4(#) 14(%) • So /Sed ment Fractionation 8(#) 29(%) • Temperature 5(#) 18(%) • W nd 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 5(#) 18(%) • D spers ng Agents 8(#) 29(%) • D sso ved Oxygen Content 6(#) 21(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 7(#) 25(%) • on c Strength n Env ronment 8(#) 29(%) • L gand Concentrations n Env ronment 7(#) 25(%) • Natura Organ c Matter (NOM) 12(#) 43(%) • Other Contaminants n Env ronment 8(#) 29(%) • pH 9(#) 32(%) • Protein Concentration n Env ronment 6(#) 21(%) • Sa n ty 8(#) 29(%) • Surfactant (in Lab) 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 3(#) 11(%) • B oaccumu ation 5(#) 18(%) • B omagn f cation 4(#) 14(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 4(#) 14(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 6(#) 21(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 4(#) 14(%) • Chron c Exposure 4(#) 14(%) • Exposure Route 3(#) 11(%) • Geograph c Location (i.e. rura vs urban) 4(#) 14(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 4(#) 14(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 2(#) 7(%) • Occupation 1(#) 4(%) • Subchron c Exposure 3(#) 11(%) • Susceptib e Popu ations/ nd v dua s 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
27	Sed ment-Mob ty	12(#) 43(%)	10(#) 36(%)	6(#) 21(%)	5(#) 18(%)	3(#) 11(%)	4(#) 14(%)	1(#) 4(%)	5(#) 18(%)	6(#) 21(%)	• App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • sed ment s kely fate of MWNTs n surface waters • Low so ub ty n water w mit mob ty un ess functiona zed • S mi ar to above, there are even more mited stud es of MWNTs n sed ments and so s and th s s the kely p ace they w be found n the env ronment • Stud es assess ng sorption of MWCNTs to so s w kely a so be app cab e to sed ments	• Ana ytica Techn ques 4(#) 14(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 5(#) 18(%) • MWCNT Synthes s Methods 1(#) 4(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 5(#) 18(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 3(#) 11(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 4(#) 14(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 14(%) • Pers stence 3(#) 11(%) • Redox Potentia 3(#) 11(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 4(#) 14(%) • Structura Formu a/Mo ecu ar Structure 3(#) 11(%) • Surface Chem stry 5(#) 18(%) • Water So ub ty/D spers b ty 4(#) 14(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 2(#) 7(%) • Sed ment 3(#) 11(%) • So 3(#) 11(%) • Surface Water 2(#) 7(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 3(#) 11(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 5(#) 18(%) • L gand Concentrations n Env ronment 4(#) 14(%) • Natura Organ c Matter (NOM) 5(#) 18(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 2(#) 7(%) • B omagn f cation 2(#) 7(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 4(%) • Chron c Exposure 1(#) 4(%) • Exposure Route 1(#) 4(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 1(#) 4(%) • L fe Stage 1(#) 4(%) • Occupation 1(#) 4(%) • Subchron c Exposure 1(#) 4(%) • Susceptib e Popu ations/ nd v dua s 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
28	Sed ment-Pers stence	12(#) 43(%)	10(#) 36(%)	6(#) 21(%)	10(#) 36(%)	2(#) 7(%)	0(#) 0(%)	2(#) 7(%)	4(#) 14(%)	6(#) 21(%)	• min mima transformation/degredation expected • We know that MWCNT are very pers stent • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • mportant to know how ong these mater a s rema n n the nano form n comp ex med a • nformation mited p 3 12 12 • W affect ength of exposure • Degradation of MWCNTs n sed ments s kely to be very s ow	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 1(#) 4(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 25(%) • Aggregation/Agg omeration State 5(#) 18(%) • App ed Coatings 7(#) 25(%) • B odegradab ty 6(#) 21(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 4(#) 14(%) • Conductive or Magnetic Properties 4(#) 14(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 14(%) • Pers stence 7(#) 25(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 3(#) 11(%) • Surface Chem stry 5(#) 18(%) • Water So ub ty/D spers b ty 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 3(#) 11(%) • Sed ment 6(#) 21(%) • So 5(#) 18(%) • Surface Water 3(#) 11(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 4(#) 14(%) • Temperature 3(#) 11(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 4(#) 14(%) • Natura Organ c Matter (NOM) 4(#) 14(%) • Other Contaminants n Env ronment 3(#) 11(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 3(#) 11(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 3(#) 11(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 3(#) 11(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 2(#) 7(%) • Exposure Route 2(#) 7(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupation 1(#) 4(%) • Subchron c Exposure 1(#) 4(%) • Susceptib e Popu ations/ nd v dua s 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
29	Sed ment-B oava ab ty	12(#) 43(%)	10(#) 36(%)	6(#) 21(%)	11(#) 39(%)	1(#) 4(%)	0(#) 0(%)	1(#) 4(%)	3(#) 11(%)	8(#) 29(%)	• microb a b of ms and benth c nvertebrates kely organ sms of concern • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • nformation mited p 3 12 12 • Native vs functiona zed form w affect b oava ab ty • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate • A number of stud es have shown mited b oaccumu ation of MWCNTs by sed ment organ sms a though b oturbation and mixing of MWCNTs n sed ments by organ sms cou d occur	• Ana ytica Techn ques 7(#) 25(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 1(#) 4(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 29(%) • Aggregation/Agg omeration State 6(#) 21(%) • App ed Coatings 8(#) 29(%) • B odegradab ty 8(#) 29(%) • Cata ytic Activ ty 3(#) 11(%) • Charge 4(#) 14(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 8(#) 29(%) • Matr x Bound vs Free 7(#) 25(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 6(#) 21(%) • Pers stence 6(#) 21(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 5(#) 18(%) • Spec f c Surface Area 4(#) 14(%) • Structura Formu a/Mo ecu ar Structure 3(#) 11(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 7(#) 25(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 2(#) 7(%) • Sed ment 5(#) 18(%) • So 4(#) 14(%) • Surface Water 2(#) 7(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 6(#) 21(%) • Temperature 3(#) 11(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 6(#) 21(%) • on c Strength n Env ronment 5(#) 18(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 6(#) 21(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 5(#) 18(%) • B omagn f cation 5(#) 18(%) • M crob a Commun ties n Env ronment 5(#) 18(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 3(#) 11(%) • Exposure Route 3(#) 11(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 3(#) 11(%) • nd v dua Activ ty Level 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupation 1(#) 4(%) • Subchron c Exposure 1(#) 4(%) • Susceptib e Popu ations/ nd v dua s 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
30	So Mob ty	10(#) 36(%)	10(#) 36(%)	8(#) 29(%)	4(#) 14(%)	4(#) 14(%)	2(#) 7(%)	2(#) 7(%)	2(#) 7(%)	6(#) 21(%)	• so app cation of WWTP s udge kely route for MWNTs to get to so So :water partition ng key to transport a ong w th eroded so • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • Our know edge about the mob ty of MWCNT s very mited and why do not know whether the test methods we use to assess mob ty of regu ar chem ca are approrp ate • Low so ub ty n water w mit mob ty un ess functiona zed • nsuff c ent data ava ab e for MWCNT so mob ty	• Ana ytica Techn ques 3(#) 11(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 0(#) 0(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 4(#) 14(%) • Aggregation/Agg omeration State 4(#) 14(%) • App ed Coatings 4(#) 14(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 2(#) 7(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 3(#) 11(%) • Matr x Bound vs Free 4(#) 14(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 14(%) • Pers stence 3(#) 11(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 2(#) 7(%) • Surface Chem stry 4(#) 14(%) • Water So ub ty/D spers b ty 3(#) 11(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 1(#) 4(%) • Sed ment 1(#) 4(%) • So 3(#) 11(%) • Surface Water 1(#) 4(%) • Wastewater 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 3(#) 11(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 3(#) 11(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 4(#) 14(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 3(#) 11(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#) 4(%) • B oaccumu ation 2(#) 7(%) • B omagn f cation 2(#) 7(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 2(#) 7(%) • Exposure Route 2(#) 7(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 2(#) 7(%) • Human Activ ty 3(#) 11(%) • nd v dua Activ ty Level 1(#) 4(%) • L fe Stage 1(#) 4(%) • Occupation 2(#) 7(%) • Subchron c Exposure 2(#) 7(%) • Susceptib e Popu ations/ nd v dua s 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
31	So Pers stence	10(#) 36(%)	10(#) 36(%)	8(#) 29(%)	9(#) 32(%)	1(#) 4(%)	0(#) 0(%)	3(#) 11(%)	2(#) 7(%)	5(#) 18(%)	• Potentia photochem ca changes n surface so • We know that MWCNT are very pers stent • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • nsuff c ent data ava ab e for MWCNT so pers stence • W affect ength of exposure	• Ana ytica Techn ques 4(#) 14(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 2(#) 7(%) • MWCNT Synthes s Methods 0(#) 0(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 4(#) 14(%) • Aggregation/Agg omeration State 3(#) 11(%) • App ed Coatings 4(#) 14(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 2(#) 7(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 4(#) 14(%) • Matr x Bound vs Free 4(#) 14(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 3(#) 11(%) • Pers stence 4(#) 14(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 3(#) 11(%) • Spec f c Surface Area 2(#) 7(%) • Structura Formu a/Mo ecu ar Structure 2(#) 7(%) • Surface Chem stry 3(#) 11(%) • Water So ub ty/D spers b ty 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 2(#) 7(%) • Sed ment 2(#) 7(%) • So 4(#) 14(%) • Surface Water 2(#) 7(%) • Wastewater 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 4(#) 14(%) • So /Sed ment Fractionation 4(#) 14(%) • Temperature 3(#) 11(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 1(#) 4(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 2(#) 7(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 3(#) 11(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 2(#) 7(%) • Sa n ty 1(#) 4(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 2(#) 7(%) • B omagn f cation 2(#) 7(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 2(#) 7(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 2(#) 7(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 2(#) 7(%) • Exposure Route 2(#) 7(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 2(#) 7(%) • L fe Stage 1(#) 4(%) • Occupation 2(#) 7(%) • Subchron c Exposure 2(#) 7(%) • Susceptib e Popu ations/ nd v dua s 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
32	So B oava ab ty	10(#) 36(%)	10(#) 36(%)	8(#) 29(%)	10(#) 36(%)	0(#) 0(%)	0(#) 0(%)	2(#) 7(%)	1(#) 4(%)	7(#) 25(%)	• potentia uptake and accuu ation n so microorgan sms nvertebrates and p ants • App cations of MWCNT unknown so unknown wh ch ev ronmenta factor w dr ve exposure, and f MWCNT were exposed to th s element, unknown what ts mob ty pers stence, and b oava ab y s • nsuff c ent data ava ab e for MWCNT so b oava ab ty • kely not very mob e, but cou d be b oava ab e to organ sms dwel ng n sub surface so s • Native vs functiona zed form w affect b oava ab ty • Our know edge about the b oava ab ty of MWCNT s very mited and why do not know whether the test methods we use to assess b oava ab ty of regu ar chem ca are approrp ate	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 0(#) 0(%) • Persona Protective Equ pment 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 4(#) 14(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 5(#) 18(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 2(#) 7(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 4(#) 14(%) • Pers stence 4(#) 14(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 2(#) 7(%) • Surface Chem stry 4(#) 14(%) • Water So ub ty/D spers b ty 4(#) 14(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 1(#) 4(%) • Sed ment 2(#) 7(%) • So 4(#) 14(%) • Surface Water 1(#) 4(%) • Wastewater 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 4(#) 14(%) • So /Sed ment Fractionation 5(#) 18(%) • Temperature 3(#) 11(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 3(#) 11(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 4(#) 14(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 5(#) 18(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 7(%) • B oaccumu ation 4(#) 14(%) • B omagn f cation 4(#) 14(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 2(#) 7(%) • Exposure Route 2(#) 7(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 1(#) 4(%) • L fe Stage 2(#) 7(%) • Occupation 1(#) 4(%) • Subchron c Exposure 2(#) 7(%) • Susceptib e Popu ations/ nd v dua s 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
33	Biota-Bioaccumulation	12(#); 43(%)	14(#); 50(%)	2(#); 7(%)	12(#); 43(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	6(#); 21(%)	6(#); 21(%)	• Applications of MWCNT unknown, so unknown which evironmental factor will drive exposure, and if MWCNT were exposed to this element, unknown what its mobility, persistence, and bioavailabily is. • Need a wider array of organisms/microcosms for studies of MWNT accumulation • Our knowledge about the bioaccumulation of MWCNT is very limited and why do not know whether the test methods we use to assess bioaccumulation of regular chemical are approrpiate • Incomplete data on accumulation of MWCNT in biota. • Numerous studies have shown limited bioaccumulation by a range of multicellular organisms but less is known about the elimination rates and about uptake by unicellular organisms or food chain transfer • where does material bioaccumulate if exposure was not airborne • No reliable studies	• Analytical Techniques 7(#); 25(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 4(#); 14(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 21(%) • Aggregation/Agglomeration State 9(#); 32(%) • Applied Coatings 8(#); 29(%) • Biodegradability 6(#); 21(%) • Catalytic Activity 1(#); 4(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 8(#); 29(%) • Matrix Bound vs. Free 8(#); 29(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 18(%) • Persistence 6(#); 21(%) • Redox Potential 4(#); 14(%) • Size/Size Distribution 8(#); 29(%) • Specific Surface Area 4(#); 14(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 7(#); 25(%) • Water Solubility/Dispersibility 7(#); 25(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 4(#); 14(%) • Sediment 4(#); 14(%) • Soil 5(#); 18(%) • Surface Water 5(#); 18(%) • Wastewater 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 3(#); 11(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 4(#); 14(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 6(#); 21(%) • Dissolved Oxygen Content 3(#); 11(%) • Exposure to Sunlight 2(#); 7(%) • Heavy Metals in Environment 4(#); 14(%) • Ionic Strength in Environment 4(#); 14(%) • Ligand Concentrations in Environment 5(#); 18(%) • Natural Organic Matter (NOM) 6(#); 21(%) • Other Contaminants in Environment 5(#); 18(%) • pH 7(#); 25(%) • Protein Concentration in Environment 7(#); 25(%) • Salinity 5(#); 18(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 8(#); 29(%) • Bioaccumulation 9(#); 32(%) • Biomagnification 9(#); 32(%) • Microbial Communities in Environment 8(#); 29(%) • Organism Health 6(#); 21(%) • Species/Individual Developmental Behavior 6(#); 21(%) • Species/Individual Feeding Behavior 7(#); 25(%) • Species/Individual Reproductive Behavior 6(#); 21(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 11(%) • Chronic Exposure 6(#); 21(%) • Exposure Route 6(#); 21(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 2(#); 7(%) • Human Activity 4(#); 14(%) • Individual Activity Level 3(#); 11(%) • Life Stage 4(#); 14(%) • Occupation 3(#); 11(%) • Subchronic Exposure 4(#); 14(%) • Susceptible Populations/Individuals 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
34	Human: Occupational-Ingestion	28(#); 100(%)	0(#); 0(%)	0(#); 0(%)	6(#); 21(%)	12(#); 43(%)	10(#); 36(%)	3(#); 11(%)	15(#); 54(%)	10(#); 36(%)	• conflicting results thus far • Incomplete data available for specifie MWCNT forms. • least probable exposure route and unlikely • Limited exposure, metabolism and transport not expected • oral toxicity would not be expected • Workers are now trained enough to not be eating materials contaminated or exposed to MWCNT • Data available but characterization is a questionmark • If there is occupational exposure, some ingestion cannot be ruled out but there are limited or no studies on this • In terms of exposure routes for particulates in the ocupational setting, ingestion is relativly unlikely although ingestion secondary to inhalation exposure (i.e. swallowing of material from the lung cleared by the mucocillary escalator) of due to had to mouth contamination. The dose recieved from these routes is likely to be low although little data exists to confirm this for CNT • Ingestion has not been well studied in terms of MWCNT exposures. Risk due to exposure is still not known • Lack of appropriately conducted studies with animals to evaluate the ingestion of MWCNT • No studies have indicated the extent to which this pathway will occur • Especially for liquid applications for CNT dried spray or splatter can easily be transferred from hand to mouth • abundant animal data • Adult population • Exposure through ingestion will be less prominent although the level of study is limited • No reliable studies	• Analytical Techniques 8(#); 29(%) • Control Technologies 8(#); 29(%) • MWCNT Processing Methods 8(#); 29(%) • MWCNT Purity 6(#); 21(%) • MWCNT Synthesis Methods 7(#); 25(%) • Personal Protective Equipment 9(#); 32(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 8(#); 29(%) • Aggregation/Agglomeration State 8(#); 29(%) • Applied Coatings 8(#); 29(%) • Biodegradability 6(#); 21(%) • Catalytic Activity 2(#); 7(%) • Charge 5(#); 18(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 2(#); 7(%) • Lipophilicity 7(#); 25(%) • Matrix Bound vs. Free 9(#); 32(%) • Morphology (e.g. aspect ratio, length, width, shape) 8(#); 29(%) • Persistence 7(#); 25(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 8(#); 29(%) • Specific Surface Area 7(#); 25(%) • Structural Formula/Molecular Structure 6(#); 21(%) • Surface Chemistry 8(#); 29(%) • Water Solubility/Dispersibility 7(#); 25(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 3(#); 11(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 1(#); 4(%) • Surface Water 2(#); 7(%) • Wastewater 1(#); 4(%) • Other 2(#); 7(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 4(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 3(#); 11(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 7(#); 25(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 5(#); 18(%) • Ionic Strength in Environment 4(#); 14(%) • Ligand Concentrations in Environment 3(#); 11(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 7(#); 25(%) • pH 6(#); 21(%) • Protein Concentration in Environment 5(#); 18(%) • Salinity 3(#); 11(%) • Surfactant (in Lab) 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 7(#); 25(%) • Bioaccumulation 7(#); 25(%) • Biomagnification 4(#); 14(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 5(#); 18(%) • Species/Individual Developmental Behavior 4(#); 14(%) • Species/Individual Feeding Behavior 6(#); 21(%) • Species/Individual Reproductive Behavior 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 9(#); 32(%) • Chronic Exposure 10(#); 36(%) • Exposure Route 10(#); 36(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 2(#); 7(%) • Human Activity 7(#); 25(%) • Individual Activity Level 6(#); 21(%) • Life Stage 5(#); 18(%) • Occupation 7(#); 25(%) • Subchronic Exposure 9(#); 32(%) • Susceptible Populations/Individuals 8(#); 29(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
35	Human: Occupational-Inhalation	28(#); 100(%)	0(#); 0(%)	0(#); 0(%)	28(#); 100(%)	0(#); 0(%)	0(#); 0(%)	9(#); 32(%)	11(#); 39(%)	8(#); 29(%)	• Data out there already on MWCNT expsoure in typical MWCNT manufacturing activities. • Relevant animal data with MWCNT demonstrating the risk of adverse lung effects (e.g., fibrosis). Animal IP studies indicate mesothelioma with MWCNT; chronic animal inhalation studies have not been completed. • Data available but characterization is a questionmark • clear risks, but conflicting results thus far • few true inhalation studies but data from instillation available; high dose studies only • Inhalation is the main route of exposure during production, but there is limited data on real time exposure levels • Insufficient studies, only inferring possible inhalation pathway p 4-20-21 • Main route of exposure • Challenges in measurement methods and lack of adequate characterisation of aerosols (reporting mass based metrics rather than size distributions, morphologies etc) and indeed the lack of scientific data of exposure level during various work activities means that the nature and quantity of actual workplace inhalation exposure is lacking although this continues to improve • Data for relevant MWCNT forms incomplete. • Most likely form of exposure, but if applied wet should not produce much of a exposure concern. • Some studies have been conducted on this pathway mainly for laboratory settings but many processes such as recycling have not been studied • studies indicate high exposures to animals results in MWCNTs staying in the body, does not appear to cause significant damage • A limited level of studies (animals and insects) have been conducted in less practical or even irrelevant experimental conditions.	• Analytical Techniques 12(#); 43(%) • Control Technologies 16(#); 57(%) • MWCNT Processing Methods 13(#); 46(%) • MWCNT Purity 10(#); 36(%) • MWCNT Synthesis Methods 11(#); 39(%) • Personal Protective Equipment 16(#); 57(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 10(#); 36(%) • Aggregation/Agglomeration State 16(#); 57(%) • Applied Coatings 15(#); 54(%) • Biodegradability 8(#); 29(%) • Catalytic Activity 4(#); 14(%) • Charge 10(#); 36(%) • Conductive or Magnetic Properties 3(#); 11(%) • Crystalline Phase 6(#); 21(%) • Lipophilicity 7(#); 25(%) • Matrix Bound vs. Free 16(#); 57(%) • Morphology (e.g. aspect ratio, length, width, shape) 16(#); 57(%) • Persistence 13(#); 46(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 16(#); 57(%) • Specific Surface Area 11(#); 39(%) • Structural Formula/Molecular Structure 8(#); 29(%) • Surface Chemistry 14(#); 50(%) • Water Solubility/Dispersibility 8(#); 29(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 15(#); 54(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 4(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 4(#); 14(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 3(#); 11(%) • Wind 7(#); 25(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 7(#); 25(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 4(#); 14(%) • Ionic Strength in Environment 3(#); 11(%) • Ligand Concentrations in Environment 2(#); 7(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 6(#); 21(%) • pH 3(#); 11(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 3(#); 11(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 10(#); 36(%) • Bioaccumulation 8(#); 29(%) • Biomagnification 4(#); 14(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 5(#); 18(%) • Species/Individual Developmental Behavior 5(#); 18(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 15(#); 54(%) • Chronic Exposure 16(#); 57(%) • Exposure Route 13(#); 46(%) • Geographic Location (i.e. rural vs. urban) 4(#); 14(%) • Habitat Structure 2(#); 7(%) • Human Activity 12(#); 43(%) • Individual Activity Level 12(#); 43(%) • Life Stage 6(#); 21(%) • Occupation 13(#); 46(%) • Subchronic Exposure 14(#); 50(%) • Susceptible Populations/Individuals 9(#); 32(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
36	Human: Occupational-Dermal	28(#); 100(%)	0(#); 0(%)	0(#); 0(%)	5(#); 18(%)	11(#); 39(%)	12(#); 43(%)	6(#); 21(%)	12(#); 43(%)	10(#); 36(%)	• Incomplete data available for specifie MWCNT forms. • There is still a considerable lack of scientific data of dermal exposure levels during various work activities yet knowledge of the dermal exposure to other poorly soluble particles could be used in place • can have clear cut tests • potential exposure route but low probability • Data available but characterization is a questionmark • If there is occupational exposure, dermal exposure cannot be ruled but evidence indicates that pure nanoparticles do not penetrate the skin and workers must be assumed to be wearing PPE such as gloves • Limited exposure and toxicity potential • not a likely route • Data out there already on MWCNT expsoure in typical MWCNT manufacturing activities. • Insufficient studies, only inferring possible inhalation pathway p 4-20-21 key route of exposure for workers handling coated textiles as they are converted into furniture (they will not wear PPE) • Little to no work done on dermal exposures in workplace- are dermal exposures even a concern? • Prelimary in vivo data indicate that MWCNT could penetrate abraided skin, however, no adverse effects have been noted todate. • Use protective gloves • No reliable studies	• Analytical Techniques 5(#); 18(%) • Control Technologies 5(#); 18(%) • MWCNT Processing Methods 5(#); 18(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 3(#); 11(%) • Personal Protective Equipment 5(#); 18(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 14(%) • Aggregation/Agglomeration State 5(#); 18(%) • Applied Coatings 5(#); 18(%) • Biodegradability 3(#); 11(%) • Catalytic Activity 1(#); 4(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 6(#); 21(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 18(%) • Persistence 4(#); 14(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 5(#); 18(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 3(#); 11(%) • Surface Chemistry 5(#); 18(%) • Water Solubility/Dispersibility 3(#); 11(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Air 2(#); 7(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 1(#); 4(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 1(#); 4(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 4(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 4(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 4(#); 14(%) • Bioaccumulation 3(#); 11(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 2(#); 7(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 18(%) • Chronic Exposure 6(#); 21(%) • Exposure Route 4(#); 14(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 4(#); 14(%) • Individual Activity Level 4(#); 14(%) • Life Stage 1(#); 4(%) • Occupation 5(#); 18(%) • Subchronic Exposure 5(#); 18(%) • Susceptible Populations/Individuals 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
37	Human Consumer ngestion	19(#) 68(%)	8(#) 29(%)	1(#) 4(%)	11(#) 39(%)	3(#) 11(%)	5(#) 18(%)	1(#) 4(%)	6(#) 21(%)	12(#) 43(%)	• Most probab e exposure route through contaminanted food • Few stud es are ava ab e on th s other than compar sons to decaBDE • No data ava ab e on consumer contact w th MWCNT f ame retardant upho stery coatings • Too tt e s known about sources to determine r sk • Rel ab e data on consumer exposure s not yet ava ab e but can estimate worst case consumer exposure • ngestion has not been wel stud ed n terms of MWCNT exposures R sk due to exposure s stil not known • nha ation s pr mary r sk w th MWCNT not ngestion • mited exposure, metabo sm and transport not expected • The kel hood of ngestion exposure to a CNT conta n ng f re retardant s kely to be very ow and f so aga n secondary to nha ation/ derma exposure • ack of data both exper menta and f eld • Lack of appropr ate exposure assessment techn ques • Ch dren mouth ng • We expect MWCNT to be pr mar y excreted but stil wou dnt eat them	• Ana ytica Techn ques 8(#) 29(%) • Contro Techno og es 4(#) 14(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 6(#) 21(%) • App ed Coatings 7(#) 25(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 4(#) 14(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 4(#) 14(%) • Matr x Bound vs Free 6(#) 21(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 18(%) • Pers stence 6(#) 21(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 5(#) 18(%) • Spec f c Surface Area 2(#) 7(%) • Structura Formu a/Mo ecu ar Structure 5(#) 18(%) • Surface Chem stry 5(#) 18(%) • Water So ub ty/D spers b ty 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 4(#) 14(%) • Groundwater 3(#) 11(%) • Sed ment 1(#) 4(%) • So 1(#) 4(%) • Surface Water 2(#) 7(%) • Wastewater 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 1(#) 4(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 3(#) 11(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 2(#) 7(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 3(#) 11(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 2(#) 7(%) • Other Contaminants n Env ronment 3(#) 11(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 6(#) 21(%) • B oaccumu ation 3(#) 11(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 1(#) 4(%) • Organ sm Hea th 3(#) 11(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 21(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 9(#) 32(%) • Geograph c Location (i.e. rura vs urban) 0(#) 0(%) • Hab tat Structure 2(#) 7(%) • Human Activ ty 7(#) 25(%) • nd v dua Activ ty Level 6(#) 21(%) • L fe Stage 3(#) 11(%) • Occupation 4(#) 14(%) • Subchron c Exposure 7(#) 25(%) • Susceptib e Popu ations/ nd v dua s 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
38	Human Consumer nha ation	19(#) 68(%)	8(#) 29(%)	1(#) 4(%)	13(#) 46(%)	5(#) 18(%)	1(#) 4(%)	2(#) 7(%)	7(#) 25(%)	10(#) 36(%)	• Due to the ear y stage n the use of CNT conta n ng products th s nformation s comp etely ack ng yet as d scussed n Chapter 2 the potentia for release s ev dent from dusts contian ng decaBDE being elease from textiles and nsu ation mater a s Therefore the evel of exposure dur ng use s mportant a though ev dence suggests potentia y a ow hazard from CNT v a derma exposure as s a so seen w th many poor y so ub e partic es • Lack of exper menta or f eld data Lack of appropr ate exposure assessment techn ques • Resuspended dust w th released MWCNT • Few stud es are ava ab e on th s other than compar sons to decaBDE • Ma n route of exposure • Potentia for da y acute exposures bu d up of product n househo d dust, etc • Rel ab e data on consumer exposure s not yet ava ab e but can estimate worst case consumer exposure. • Too tt e s known about sources to determine r sk • Low kel hood for exposure n products • App cations of MWCNT not wel defined so consumer use wh ch cou d ead to release wh ch wou d n turn ead to exposures unknown • No data ava ab e on consumer contact w th MWCNT f ame retardant upho stery coatings • Once embedded nto a po ymer or a surface coating exposure through nha ation s expected to be min ma	• Ana ytica Techn ques 10(#) 36(%) • Contro Techno og es 7(#) 25(%) • MWCNT Process ng Methods 5(#) 18(%) • MWCNT Pur ty 7(#) 25(%) • MWCNT Synthes s Methods 5(#) 18(%) • Persona Protective Equ pment 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 8(#) 29(%) • Aggregation/Agg omeration State 11(#) 39(%) • App ed Coatings 10(#) 36(%) • B odegradab ty 8(#) 29(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 5(#) 18(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 11(#) 39(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 10(#) 36(%) • Redox Potentia 5(#) 18(%) • S ze/S ze D str bution 11(#) 39(%) • Spec f c Surface Area 7(#) 25(%) • Structura Formu a/Mo ecu ar Structure 7(#) 25(%) • Surface Chem stry 8(#) 29(%) • Water So ub ty/D spers b ty 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 12(#) 43(%) • Groundwater 0(#) 0(%) • Sed ment 1(#) 4(%) • So 3(#) 11(%) • Surface Water 2(#) 7(%) • Wastewater 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 4(#) 14(%) • W nd 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 3(#) 11(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 2(#) 7(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 2(#) 7(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 2(#) 7(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 5(#) 18(%) • B oaccumu ation 4(#) 14(%) • B omagn f cation 4(#) 14(%) • M crob a Commun ties n Env ronment 1(#) 4(%) • Organ sm Hea th 4(#) 14(%) • Spec es/ nd v dua Developmenta Behav or 5(#) 18(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 10(#) 36(%) • Chron c Exposure 11(#) 39(%) • Exposure Route 10(#) 36(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 9(#) 32(%) • nd v dua Activ ty Level 8(#) 29(%) • L fe Stage 7(#) 25(%) • Occupation 5(#) 18(%) • Subchron c Exposure 11(#) 39(%) • Susceptib e Popu ations/ nd v dua s 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
39	Human: Consumer-Dermal	19(#); 68(%)	8(#); 29(%)	1(#); 4(%)	5(#); 18(%)	6(#); 21(%)	8(#); 29(%)	3(#); 11(%)	3(#); 11(%)	13(#); 46(%)	• No data available on consumer contact with MWCNT flame retardant upholstery coatings. • Lack of experimental or field data. Lack of appropriate exposure assessment techniques. • Low likelihood for exposure in products • Applications of MWCNT not well defined, so consumer use which could lead to release which would in turn lead to exposures unknown. Plus, inhalation is primary concern, not dermal. • Dermal exposure does not seem to be a risk. Not well studied. • Limited exposure, contained in polymer matrix • Not a likely route • No reliable techniqes for estimating gen pop exposures. • Constant contact with skin from upholstery could lead to potential exposure • Due to the early stage in th use of CNT containing products, this information is completely lacking yet as discussed in Chapter 2, the potential for release is evident from dusts contianing decaBDE being elease from textiles and insulation materials. Therefore the level of exposure during use is important although evidence suggests potentially a low hazard from CNT via dermal exposure as is also seen with many poorly soluble particles. • Few studies are available on this other than comparisons to decaBDE.	• Analytical Techniques 6(#); 21(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 18(%) • Aggregation/Agglomeration State 6(#); 21(%) • Applied Coatings 6(#); 21(%) • Biodegradability 4(#); 14(%) • Catalytic Activity 1(#); 4(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 4(#); 14(%) • Matrix Bound vs. Free 6(#); 21(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 18(%) • Persistence 4(#); 14(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 5(#); 18(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 3(#); 11(%) • Surface Chemistry 5(#); 18(%) • Water Solubility/Dispersibility 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 2(#); 7(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 2(#); 7(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 2(#); 7(%) • pH 1(#); 4(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 18(%) • Bioaccumulation 3(#); 11(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 3(#); 11(%) • Species/Individual Developmental Behavior 4(#); 14(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 7(#); 25(%) • Chronic Exposure 7(#); 25(%) • Exposure Route 5(#); 18(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 2(#); 7(%) • Human Activity 7(#); 25(%) • Individual Activity Level 7(#); 25(%) • Life Stage 3(#); 11(%) • Occupation 3(#); 11(%) • Subchronic Exposure 6(#); 21(%) • Susceptible Populations/Individuals 6(#); 21(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
40	Human: General Population-Ingestion	6(#); 21(%)	16(#); 57(%)	6(#); 21(%)	1(#); 4(%)	3(#); 11(%)	2(#); 7(%)	1(#); 4(%)	1(#); 4(%)	4(#); 14(%)	• Most likely route of exposure • Applications of MWCNT not well defined, so consumer use which could lead to release which would in turn lead to exposures unknown. Plus, inhalation is primary concern, not ingestion. • Lack of data • No reliable techniques for estimating general population exposures	• Analytical Techniques 2(#); 7(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 2(#); 7(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 1(#); 4(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 1(#); 4(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 4(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 1(#); 4(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 4(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 1(#); 4(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
41	Human: General Population-Inhalation	6(#); 21(%)	16(#); 57(%)	6(#); 21(%)	2(#); 7(%)	3(#); 11(%)	1(#); 4(%)	1(#); 4(%)	1(#); 4(%)	4(#); 14(%)	• Too little is known about sources to determine risk • Likely route of exposure • Applications of MWCNT not well defined, so consumer use which would lead to release which would in turn lead to exposures unknown. • No reliable techniqes for estimating general population exposures	• Analytical Techniques 3(#); 11(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 3(#); 11(%) • Applied Coatings 3(#); 11(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 2(#); 7(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 4(#); 14(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 4(#); 14(%) • Redox Potential 2(#); 7(%) • Size/Size Distribution 3(#); 11(%) • Specific Surface Area 3(#); 11(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 3(#); 11(%) • Water Solubility/Dispersibility 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 2(#); 7(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 2(#); 7(%) • Wind 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 1(#); 4(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 7(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 3(#); 11(%) • Exposure Route 3(#); 11(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 1(#); 4(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 2(#); 7(%) • Occupation 1(#); 4(%) • Subchronic Exposure 3(#); 11(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
42	Human: General Population-Dermal	6(#); 21(%)	16(#); 57(%)	6(#); 21(%)	0(#); 0(%)	1(#); 4(%)	5(#); 18(%)	1(#); 4(%)	1(#); 4(%)	4(#); 14(%)	• Little absorption • Applications of MWCNT not well defined, so consumer use which could lead to release which would in turn lead to exposures unknown. Plus, inhalation is primary concern, not dermal. • Not a likely route • No reliable techniqes for estimating gen pop exposures No reliable techniqes for estimating general population exposures
43	Aquatic Biota-Ingestion	5(#); 18(%)	18(#); 64(%)	5(#); 18(%)	5(#); 18(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	2(#); 7(%)	2(#); 7(%)	• Most likely route of exposure • A wider variety of species studies is necessary to make conclusions about environmental safety • Ingestion for aquatic biota is very relevant
44	Aquatic Biota-Inhalation	5(#); 18(%)	18(#); 64(%)	5(#); 18(%)	0(#); 0(%)	1(#); 4(%)	4(#); 14(%)	1(#); 4(%)	1(#); 4(%)	3(#); 11(%)	• Not air breathers

ID	Influential Factors						
	Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
42	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
43	• Analytical Techniques 2(#); 7(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 3(#); 11(%) • Applied Coatings 2(#); 7(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 3(#); 11(%) • Matrix Bound vs. Free 3(#); 11(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 3(#); 11(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 4(%) • Sediment 2(#); 7(%) • Soil 2(#); 7(%) • Surface Water 3(#); 11(%) • Wastewater 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 2(#); 7(%) • Natural Organic Matter (NOM) 3(#); 11(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 3(#); 11(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 11(%) • Bioaccumulation 3(#); 11(%) • Biomagnification 3(#); 11(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 3(#); 11(%) • Exposure Route 3(#); 11(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 0(#); 0(%) • Individual Activity Level 2(#); 7(%) • Life Stage 3(#); 11(%) • Occupation 1(#); 4(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
44	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
45	Aquatic Biota-Direct Contact	5(#); 18(%)	18(#); 64(%)	5(#); 18(%)	4(#); 14(%)	1(#); 4(%)	0(#); 0(%)	1(#); 4(%)	3(#); 11(%)	1(#); 4(%)	• Little likelihood of uptake across skin/carapice; only important for biofilms	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 4(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 4(%) • Sediment 2(#); 7(%) • Soil 1(#); 4(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 7(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 2(#); 7(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 2(#); 7(%) • Life Stage 2(#); 7(%) • Occupation 1(#); 4(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
46	Terrestrial Biota-Ingestion	2(#); 7(%)	20(#); 71(%)	6(#); 21(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	1(#); 4(%)	• Food web studies are critical to understanding potential environmental and human impacts	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 0(#); 0(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 4(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 4(%) • Sediment 1(#); 4(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 1(#); 4(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
47	Terrestrial Biota-Inhalation	2(#); 7(%)	20(#); 71(%)	6(#); 21(%)	0(#); 0(%)	1(#); 4(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)	1(#); 4(%)		• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 4(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
48	Terrestrial Biota-Direct Contact	2(#); 7(%)	20(#); 71(%)	6(#); 21(%)	0(#); 0(%)	1(#); 4(%)	1(#); 4(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
49	Abiotic-Direct Contact	1(#); 4(%)	8(#); 29(%)	19(#); 68(%)	0(#); 0(%)	1(#); 4(%)	0(#); 0(%)	0(#); 0(%)	1(#); 4(%)	0(#); 0(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
50	Human Absorption	26(#) 93(%)	2(#) 7(%)	0(#) 0(%)	22(#) 79(%)	3(#) 11(%)	1(#) 4(%)	2(#) 7(%)	6(#) 21(%)	18(#) 64(%)	• Need to quantify absorption to determine f exposure occurs • ADME s v ta n order to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Cha enges exist n dentify ng and character s ng CNT n v vo espec a y n terms measur ng uptake, d str bution and c earance rates through the body The nature of absorption and penetration of CNT nto the body espec a y the effect of s ze, shape etc has on regiona depos tion n the ung s mportant and ack ng • Lack of data Section 4 2 6 • MWCNT dose ssues unknown • No data ava ab e on MWCNT dos ng n humans • No data but cannot rea y study n humans can t rea y study MWCNTs n textiles un ess t can be found n the b ood or ur ne and that ooks un kely need nv tro tests such as derma penetration of the powder to understand worst case f t s absorbed and f so where t goes • Not enough known on concentration n ungs adsorption n ungs s key • Some qua tative data s ava ab e for MWCNTs after nha ation stud es but tt e nformation s ava ab e for derma or ora ngestion stud es • Some rodent data exists • L mited data on other ENPs nd cate that absorption s a min ma to tt e r sk • Data does not yet exist and most known CNT effects do not depend on these elements • Probab y ow so ub ty so ess chance of absorption • No rel ab e stud es	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 6(#) 21(%) • MWCNT Process ng Methods 9(#) 32(%) • MWCNT Pur ty 10(#) 36(%) • MWCNT Synthes s Methods 8(#) 29(%) • Persona Protective Equ pment 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 15(#) 54(%) • Aggregation/Agg omeration State 16(#) 57(%) • App ed Coatings 13(#) 46(%) • B odegradab ty 10(#) 36(%) • Cata ytic Activ ty 7(#) 25(%) • Charge 12(#) 43(%) • Conductive or Magnetic Properties 6(#) 21(%) • Crysta ne Phase 3(#) 11(%) • L poph c ty 15(#) 54(%) • Matr x Bound vs Free 16(#) 57(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 18(#) 64(%) • Pers stence 12(#) 43(%) • Redox Potentia 6(#) 21(%) • S ze/S ze D str bution 15(#) 54(%) • Spec f c Surface Area 13(#) 46(%) • Structura Formu a/Mo ecu ar Structure 11(#) 39(%) • Surface Chem stry 15(#) 54(%) • Water So ub ty/D spers b ty 17(#) 61(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 4(#) 14(%) • Sed ment 2(#) 7(%) • So 4(#) 14(%) • Surface Water 6(#) 21(%) • Wastewater 4(#) 14(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 3(#) 11(%) • So Poros ty 3(#) 11(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 6(#) 21(%) • W nd 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 10(#) 36(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 6(#) 21(%) • on c Strength n Env ronment 6(#) 21(%) • L gand Concentrations n Env ronment 6(#) 21(%) • Natura Organ c Matter (NOM) 7(#) 25(%) • Other Contaminants n Env ronment 6(#) 21(%) • pH 10(#) 36(%) • Protein Concentration n Env ronment 11(#) 39(%) • Sa n ty 8(#) 29(%) • Surfactant (in Lab) 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 14(#) 50(%) • B oaccumu ation 14(#) 50(%) • B omagn f cation 7(#) 25(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 10(#) 36(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 14(%) • Spec es/ nd v dua Feed ng Behav or 8(#) 29(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 15(#) 54(%) • Chron c Exposure 16(#) 57(%) • Exposure Route 17(#) 61(%) • Geograph c Location (i.e. rura vs urban) 5(#) 18(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 7(#) 25(%) • nd v dua Activ ty Level 9(#) 32(%) • L fe Stage 9(#) 32(%) • Occupation 9(#) 32(%) • Subchron c Exposure 14(#) 50(%) • Susceptib e Popu ations/ nd v dua s 12(#) 43(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
51	Human D str bution	26(#) 93(%)	2(#) 7(%)	0(#) 0(%)	20(#) 71(%)	6(#) 21(%)	0(#) 0(%)	2(#) 7(%)	6(#) 21(%)	18(#) 64(%)	• f absorption occurs th s s cr tica • ADME s v ta n order to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Cha enges exist n dentify ng and character s ng CNT n v vo espec a y n terms measur ng uptake, d str bution and c earance rates through the body a though stud es are beginn ng to conf rm the ab ty of CNT from the ung to the p eura (a though the Mercer 2010 study wh h best shows th s s not mentioned n the document) • Lack of data Section 4 2 6 oca zed accumu ation cou d be a prob em • MWCNT dose ssues unknown • No data ava ab e on MWCNT dos ng n humans • Few stud es show d str bution throughout organ sms after nha ation or ora exposures Most MWCNTs rema n near where they entered the organ sm or are excreted • Some rodent data exists • May undergo transport, espec a y functiona zed mater a not enough known • Not much ev dence on f d str bution throughout body occurs • Data does not yet exist and most known CNT effects do not depend on these elements • L mited an ma data nd cates that MWCNT depos ted n the ung can transport systemica y to other organs • Study des gns used for an ma stud es do not reflect rea fe cond tions • Probab y ow so ub ty so ess chance of d str bution • No rel ab e stud es	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 4(#) 14(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 9(#) 32(%) • MWCNT Synthes s Methods 7(#) 25(%) • Persona Protective Equ pment 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 12(#) 43(%) • Aggregation/Agg omeration State 14(#) 50(%) • App ed Coatings 12(#) 43(%) • B odegradab ty 13(#) 46(%) • Cata ytic Activ ty 7(#) 25(%) • Charge 10(#) 36(%) • Conductive or Magnetic Properties 5(#) 18(%) • Crysta ne Phase 3(#) 11(%) • L poph c ty 14(#) 50(%) • Matr x Bound vs Free 15(#) 54(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 16(#) 57(%) • Pers stence 12(#) 43(%) • Redox Potentia 7(#) 25(%) • S ze/S ze D str bution 14(#) 50(%) • Spec f c Surface Area 11(#) 39(%) • Structura Formu a/Mo ecu ar Structure 10(#) 36(%) • Surface Chem stry 13(#) 46(%) • Water So ub ty/D spers b ty 17(#) 61(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 25(%) • Groundwater 4(#) 14(%) • Sed ment 2(#) 7(%) • So 2(#) 7(%) • Surface Water 4(#) 14(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 5(#) 18(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 10(#) 36(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 5(#) 18(%) • on c Strength n Env ronment 7(#) 25(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 5(#) 18(%) • Other Contaminants n Env ronment 5(#) 18(%) • pH 8(#) 29(%) • Protein Concentration n Env ronment 10(#) 36(%) • Sa n ty 6(#) 21(%) • Surfactant (in Lab) 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 14(#) 50(%) • B oaccumu ation 14(#) 50(%) • B omagn f cation 8(#) 29(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 11(#) 39(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 14(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 25(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 14(#) 50(%) • Chron c Exposure 15(#) 54(%) • Exposure Route 16(#) 57(%) • Geograph c Location (i.e. rura vs urban) 3(#) 11(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 6(#) 21(%) • nd v dua Activ ty Level 9(#) 32(%) • L fe Stage 9(#) 32(%) • Occupation 6(#) 21(%) • Subchron c Exposure 13(#) 46(%) • Susceptib e Popu ations/ nd v dua s 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
52	Human Metabo sm	26(#) 93(%)	2(#) 7(%)	0(#) 0(%)	12(#) 43(%)	9(#) 32(%)	5(#) 18(%)	2(#) 7(%)	5(#) 18(%)	19(#) 68(%)	• ADME s v ta n order to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Lack of data Section 4 2 6 • Study des gns used for an ma stud es do not reflect rea fe cond tions • MWCNT dose ssues unknown No data ava ab e on MWCNT dos ng n humans • Potentia products of metabo sm may prov de toxic ty routes naccess b e by arger MWCNTs • Remova from ungs s unknown • t s un kely that substantia MWCNT metabo sm w occur • Data says most MWCNTs are el minated after ngestion • L mited data on metabo sm and absorption • Data does not yet exist and most known CNT effects do not depend on these elements • Some an ma data nd cate that MWCNT can transport to the other n ngs of the ung and to the card ovascu ar system. The metabo c pathway seems dependent on the organ n wh ch MWCNT are depos ted • The chem ca nature of CNT and observed b opers stence means that metabo sm s un k y to resu t n mod f cation of the CNT or production of toxic metabo tes etc a though the metabo sm of contaminating substances formed dur ng production etc may be of nterest • Agree that MWCNTs are un kely to be metabo zed (other than to carboxy c ac ds wh ch are el minated) un ess there s a metabo zab e functiona group added on the MWCNTs • Does not need to be metabo zed • Probab y ow metabo sm potentia but not much data on th s • No rel ab e stud es	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 5(#) 18(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 11(#) 39(%) • MWCNT Synthes s Methods 8(#) 29(%) • Persona Protective Equ pment 5(#) 18(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 11(#) 39(%) • Aggregation/Agg omeration State 11(#) 39(%) • App ed Coatings 11(#) 39(%) • B odegradab ty 12(#) 43(%) • Cata ytic Activ ty 7(#) 25(%) • Charge 9(#) 32(%) • Conductive or Magnetic Properties 5(#) 18(%) • Crysta ne Phase 4(#) 14(%) • L poph c ty 12(#) 43(%) • Matr x Bound vs Free 12(#) 43(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 13(#) 46(%) • Pers stence 12(#) 43(%) • Redox Potentia 8(#) 29(%) • S ze/S ze D str bution 11(#) 39(%) • Spec f c Surface Area 9(#) 32(%) • Structura Formu a/Mo ecu ar Structure 8(#) 29(%) • Surface Chem stry 13(#) 46(%) • Water So ub ty/D spers b ty 15(#) 54(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• A r 8(#) 29(%) • Groundwater 4(#) 14(%) • Sed ment 2(#) 7(%) • So 2(#) 7(%) • Surface Water 3(#) 11(%) • Wastewater 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 3(#) 11(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 5(#) 18(%) • W nd 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 9(#) 32(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 7(#) 25(%) • on c Strength n Env ronment 5(#) 18(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 6(#) 21(%) • Other Contaminants n Env ronment 8(#) 29(%) • pH 9(#) 32(%) • Protein Concentration n Env ronment 9(#) 32(%) • Sa n ty 5(#) 18(%) • Surfactant (in Lab) 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 11(#) 39(%) • B oaccumu ation 11(#) 39(%) • B omagn f cation 7(#) 25(%) • M crob a Commun ties n Env ronment 5(#) 18(%) • Organ sm Hea th 9(#) 32(%) • Spec es/ nd v dua Developmenta Behav or 4(#) 14(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 25(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 13(#) 46(%) • Chron c Exposure 13(#) 46(%) • Exposure Route 12(#) 43(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 6(#) 21(%) • nd v dua Activ ty Level 9(#) 32(%) • L fe Stage 10(#) 36(%) • Occupation 6(#) 21(%) • Subchron c Exposure 12(#) 43(%) • Susceptib e Popu ations/ nd v dua s 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
53	Human Excretion	26(#) 93(%)	2(#) 7(%)	0(#) 0(%)	16(#) 57(%)	8(#) 29(%)	2(#) 7(%)	2(#) 7(%)	6(#) 21(%)	18(#) 64(%)	• f absorption occurs th s s cr tica • Data says most MWCNTs are el minated after ngestion (elimination not ust excretion) • Study des gns used for an ma stud es do not reflect rea fe cond tions • ADME s v ta n order to understand toxic ty of chem ca s n genera and hence a so very relevant for MWCNTs We need the ana ytica methods to assess ADME of MWCNTs • Cha enges exist n dentify ng and character s ng CNT n v vo n terms c earance rates through the body and routes of excretion based on d ffer ng routes of exposure. Some stud es do exist show ng ur nary excretion of SWCNT after ntravenous n ection but such stud es are of ow relevance to the use of CNT and subsquent exposure routes as descr bed n th s CEA • Lack of data Section 4 2 6 Some ong time pers stence has been observed after ung exposures • MWCNT does ssues unknown • No data ava ab e on MWCNT dos ng n humans • Lack of relevant pub shed data • Not expected to be absorbed n gut • PK stud es have not been done • Data does not yet exist and most known CNT effects do not depend on these elements • Relatively c ear modes of excretion • Probab y excreted but some may rema n n ver or k dneys • No rel ab e stud es	• Ana ytica Techn ques 13(#) 46(%) • Contro Techno og es 4(#) 14(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 10(#) 36(%) • MWCNT Synthes s Methods 8(#) 29(%) • Persona Protective Equ pment 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 36(%) • Aggregation/Agg omeration State 12(#) 43(%) • App ed Coatings 9(#) 32(%) • B odegradab ty 11(#) 39(%) • Cata ytic Activ ty 5(#) 18(%) • Charge 8(#) 29(%) • Conductive or Magnetic Properties 5(#) 18(%) • Crysta ne Phase 3(#) 11(%) • L poph c ty 13(#) 46(%) • Matr x Bound vs Free 13(#) 46(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 14(#) 50(%) • Pers stence 12(#) 43(%) • Redox Potentia 6(#) 21(%) • S ze/S ze D str bution 13(#) 46(%) • Spec f c Surface Area 9(#) 32(%) • Structura Formu a/Mo ecu ar Structure 8(#) 29(%) • Surface Chem stry 14(#) 50(%) • Water So ub ty/D spers b ty 16(#) 57(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 25(%) • Groundwater 5(#) 18(%) • Sed ment 2(#) 7(%) • So 2(#) 7(%) • Surface Water 4(#) 14(%) • Wastewater 3(#) 11(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 5(#) 18(%) • W nd 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 4(#) 14(%) • D spers ng Agents 9(#) 32(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 3(#) 11(%) • Heavy Meta s n Env ronment 5(#) 18(%) • on c Strength n Env ronment 6(#) 21(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 5(#) 18(%) • Other Contaminants n Env ronment 5(#) 18(%) • pH 9(#) 32(%) • Protein Concentration n Env ronment 10(#) 36(%) • Sa n ty 7(#) 25(%) • Surfactant (in Lab) 7(#) 25(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 15(#) 54(%) • B oaccumu ation 13(#) 46(%) • B omagn f cation 7(#) 25(%) • M crob a Commun ties n Env ronment 4(#) 14(%) • Organ sm Hea th 11(#) 39(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 25(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 11(#) 39(%) • Chron c Exposure 12(#) 43(%) • Exposure Route 13(#) 46(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 4(#) 14(%) • nd v dua Activ ty Level 7(#) 25(%) • L fe Stage 8(#) 29(%) • Occupation 5(#) 18(%) • Subchron c Exposure 10(#) 36(%) • Susceptib e Popu ations/ nd v dua s 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
54	Aquatic B ota Absorption	13(#) 46(%)	12(#) 43(%)	3(#) 11(%)	12(#) 43(%)	0(#) 0(%)	1(#) 4(%)	2(#) 7(%)	5(#) 18(%)	6(#) 21(%)	• Need to quantify absorption to determine f exposure occurs • MWCNT dose ssues unknown • Need to determine f b ota absorbs MWCNTs • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ronments n order to character se uptake, d str butions or remova from ecosystems n add tion there are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t wh ch therefore may mpact on the ab ty of measur ng excretion rates • Data s over y emp r ca • L mited data • Study des gns used for an ma stud es do not reflect rea fe cond tions • Very few stud es n th s area often hampered by ack of w dely access b e methods for quantif cation • Many stud es have shown a ack of absorption of MWCNTs nto tissues	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 3(#) 11(%) • Persona Protective Equ pment 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 25(%) • Aggregation/Agg omeration State 8(#) 29(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 4(#) 14(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 8(#) 29(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 5(#) 18(%) • Redox Potentia 2(#) 7(%) • S ze/S ze D str bution 8(#) 29(%) • Spec f c Surface Area 5(#) 18(%) • Structura Formu a/Mo ecu ar Structure 5(#) 18(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 5(#) 18(%) • Sed ment 5(#) 18(%) • So 3(#) 11(%) • Surface Water 6(#) 21(%) • Wastewater 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 2(#) 7(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 4(#) 14(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 4(#) 14(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 5(#) 18(%) • L gand Concentrations n Env ronment 5(#) 18(%) • Natura Organ c Matter (NOM) 7(#) 25(%) • Other Contaminants n Env ronment 3(#) 11(%) • pH 5(#) 18(%) • Protein Concentration n Env ronment 6(#) 21(%) • Sa n ty 5(#) 18(%) • Surfactant (in Lab) 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 25(%) • B oaccumu ation 5(#) 18(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 3(#) 11(%) • Organ sm Hea th 5(#) 18(%) • Spec es/ nd v dua Developmenta Behav or 1(#) 4(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 6(#) 21(%) • Chron c Exposure 6(#) 21(%) • Exposure Route 5(#) 18(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 2(#) 7(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 3(#) 11(%) • L fe Stage 3(#) 11(%) • Occupation 1(#) 4(%) • Subchron c Exposure 4(#) 14(%) • Susceptib e Popu ations/ nd v dua s 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
55	Aquatic B ota D str bution	13(#) 46(%)	12(#) 43(%)	3(#) 11(%)	12(#) 43(%)	0(#) 0(%)	1(#) 4(%)	2(#) 7(%)	2(#) 7(%)	9(#) 32(%)	• f absorption occurs th s s cr tica • MWCNT dose ssues unknown • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ornements n order to charater se uptake, d str butions or remova from ecosystems • Very few stud es n these area often hampered by ack of w dely access b e methods for quantif cation • Data s over y emp r ca • L mited data • Study des gns used for an ma stud es do not reflect rea fe cond tions • Many stud es have shown a ack of absorption of MWCNTs nto tissues	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 2(#) 7(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 3(#) 11(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 7(#) 25(%) • Aggregation/Agg omeration State 8(#) 29(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 6(#) 21(%) • Cata ytic Activ ty 3(#) 11(%) • Charge 5(#) 18(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 6(#) 21(%) • Matr x Bound vs Free 7(#) 25(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 6(#) 21(%) • Redox Potentia 3(#) 11(%) • S ze/S ze D str bution 7(#) 25(%) • Spec f c Surface Area 5(#) 18(%) • Structura Formu a/Mo ecu ar Structure 6(#) 21(%) • Surface Chem stry 8(#) 29(%) • Water So ub ty/D spers b ty 9(#) 32(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 5(#) 18(%) • Sed ment 5(#) 18(%) • So 4(#) 14(%) • Surface Water 6(#) 21(%) • Wastewater 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 4(#) 14(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 2(#) 7(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 6(#) 21(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 5(#) 18(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 8(#) 29(%) • B oaccumu ation 7(#) 25(%) • B omagn f cation 6(#) 21(%) • M crob a Commun ties n Env ronment 3(#) 11(%) • Organ sm Hea th 7(#) 25(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 18(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 7(#) 25(%) • Chron c Exposure 7(#) 25(%) • Exposure Route 6(#) 21(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 1(#) 4(%) • nd v dua Activ ty Level 3(#) 11(%) • L fe Stage 4(#) 14(%) • Occupation 2(#) 7(%) • Subchron c Exposure 5(#) 18(%) • Susceptib e Popu ations/ nd v dua s 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
56	Aquatic Biota-Metabolism	13(#); 46(%)	12(#); 43(%)	3(#); 11(%)	5(#); 18(%)	1(#); 4(%)	7(#); 25(%)	1(#); 4(%)	2(#); 7(%)	10(#); 36(%)	• MWCNT dose issues unknown • Very few studies in these area, often hampered by lack of widely accessible methods for quantification • If absorption occurs this is critical • Similar challenges as for human studies in terms of monitoring particles in complex envionments in order to charaterise uptake, distributions or removal from ecosystems. • Data is overly empirical • Limited data • Study designs used for animal studies do not reflect real-life conditions. • MWCNTs are expected to be fairly resistant to metabolism • Becomes more important if absorbed	• Analytical Techniques 3(#); 11(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 11(%) • Aggregation/Agglomeration State 3(#); 11(%) • Applied Coatings 3(#); 11(%) • Biodegradability 4(#); 14(%) • Catalytic Activity 2(#); 7(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 4(#); 14(%) • Matrix Bound vs. Free 4(#); 14(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 14(%) • Persistence 4(#); 14(%) • Redox Potential 3(#); 11(%) • Size/Size Distribution 3(#); 11(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 3(#); 11(%) • Surface Chemistry 4(#); 14(%) • Water Solubility/Dispersibility 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 3(#); 11(%) • Sediment 3(#); 11(%) • Soil 2(#); 7(%) • Surface Water 4(#); 14(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 3(#); 11(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 3(#); 11(%) • Dissolved Oxygen Content 4(#); 14(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 2(#); 7(%) • Ligand Concentrations in Environment 2(#); 7(%) • Natural Organic Matter (NOM) 4(#); 14(%) • Other Contaminants in Environment 2(#); 7(%) • pH 3(#); 11(%) • Protein Concentration in Environment 4(#); 14(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 18(%) • Bioaccumulation 3(#); 11(%) • Biomagnification 3(#); 11(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 3(#); 11(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 14(%) • Chronic Exposure 4(#); 14(%) • Exposure Route 3(#); 11(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 4(%) • Individual Activity Level 3(#); 11(%) • Life Stage 3(#); 11(%) • Occupation 1(#); 4(%) • Subchronic Exposure 3(#); 11(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
57	Aquatic B ota Excretion	13(#) 46(%)	12(#) 43(%)	3(#) 11(%)	9(#) 32(%)	2(#) 7(%)	2(#) 7(%)	1(#) 4(%)	4(#) 14(%)	8(#) 29(%)	• f absorption occurs th s s cr tica • MWCNT dose ssues unknown • S mi ar cha enges as for human stud es n terms of mon tor ng partic es n comp ex env ornements n order to character se uptake, d str butions or remova from ecosystems n add tion there are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t wh ch therefore may mpact on the ab ty of measur ng excretion rates • Very few stud es n these area often hampered by ack of w dely access b e methods for quantif cation • L mited data • Study des gns used for an ma stud es do not reflect rea fe cond tions • D fferent stud es have shown d fferent extents to wh ch organ sms can excrete MWCNTs accumu ated n the gut tract • Becomes more mportant f absorbed • Data s over y emp r ca	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 1(#) 4(%) • MWCNT Process ng Methods 2(#) 7(%) • MWCNT Pur ty 3(#) 11(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 6(#) 21(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 6(#) 21(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 4(#) 14(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 5(#) 18(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 7(#) 25(%) • Pers stence 5(#) 18(%) • Redox Potentia 1(#) 4(%) • S ze/S ze D str bution 5(#) 18(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#) 4(%) • Groundwater 3(#) 11(%) • Sed ment 4(#) 14(%) • So 2(#) 7(%) • Surface Water 5(#) 18(%) • Wastewater 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 0(#) 0(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 3(#) 11(%) • W nd 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 3(#) 11(%) • D sso ved Oxygen Content 3(#) 11(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 2(#) 7(%) • on c Strength n Env ronment 3(#) 11(%) • L gand Concentrations n Env ronment 2(#) 7(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 2(#) 7(%) • pH 3(#) 11(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 2(#) 7(%) • Other 1(#) 4(%) • Spec fy other 0(#) 0(%)	• ADME 7(#) 25(%) • B oaccumu ation 6(#) 21(%) • B omagn f cation 5(#) 18(%) • M crob a Commun ties n Env ronment 3(#) 11(%) • Organ sm Hea th 5(#) 18(%) • Spec es/ nd v dua Developmenta Behav or 2(#) 7(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 18(%) • Spec es/ nd v dua Reproductive Behav or 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 18(%) • Chron c Exposure 5(#) 18(%) • Exposure Route 4(#) 14(%) • Geograph c Location (i.e. rura vs urban) 0(#) 0(%) • Hab tat Structure 0(#) 0(%) • Human Activ ty 1(#) 4(%) • nd v dua Activ ty Level 3(#) 11(%) • L fe Stage 4(#) 14(%) • Occupation 2(#) 7(%) • Subchron c Exposure 4(#) 14(%) • Susceptib e Popu ations/ nd v dua s 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
58	Terrestrial Biota-Absorption	5(#); 18(%)	16(#); 57(%)	7(#); 25(%)	3(#); 11(%)	2(#); 7(%)	0(#); 0(%)	1(#); 4(%)	1(#); 4(%)	3(#); 11(%)	• Need to quantify absorption to determine if exposure occurs • MWCNT dose issues unknown • Very few studies in these area, often hampered by lack of widely accessible methods for quantification • Absorption studies of CNTs by biota are not comprehensive.	• Analytical Techniques 2(#); 7(%) • Control Technologies 1(#); 4(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 2(#); 7(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 1(#); 4(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 3(#); 11(%) • Matrix Bound vs. Free 3(#); 11(%) • Morphology (e.g. aspect ratio, length, width, shape) 3(#); 11(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 3(#); 11(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 3(#); 11(%) • Water Solubility/Dispersibility 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 11(%) • Groundwater 3(#); 11(%) • Sediment 2(#); 7(%) • Soil 3(#); 11(%) • Surface Water 3(#); 11(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 2(#); 7(%) • Exposure to Sunlight 2(#); 7(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 2(#); 7(%) • Ligand Concentrations in Environment 2(#); 7(%) • Natural Organic Matter (NOM) 3(#); 11(%) • Other Contaminants in Environment 2(#); 7(%) • pH 2(#); 7(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 7(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 2(#); 7(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 2(#); 7(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 2(#); 7(%) • Occupation 1(#); 4(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
59	Terrestrial Biota-Distribution	5(#); 18(%)	16(#); 57(%)	7(#); 25(%)	2(#); 7(%)	3(#); 11(%)	0(#); 0(%)	1(#); 4(%)	2(#); 7(%)	2(#); 7(%)	• If absorption occurs this is critical • MWCNT dose issues unknown • Very few studies in these area, often hampered by lack of widely accessible methods for quantification • Ultrafine particles and nano material distribution in biota have been conducted by phytoremediation groups.	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 4(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 2(#); 7(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
60	Terrestrial Biota-Metabolism	5(#); 18(%)	16(#); 57(%)	7(#); 25(%)	1(#); 4(%)	2(#); 7(%)	2(#); 7(%)	1(#); 4(%)	1(#); 4(%)	3(#); 11(%)	• If absorption occurs this is critical • MWCNT dose issues unknown • Very few studies in these area, often hampered by lack of widely accessible methods for quantification • Ultrafine particles and nano material distribution in biota have been conducted by phytoremediation groups.	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 1(#); 4(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 2(#); 7(%) • Redox Potential 2(#); 7(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 4(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 2(#); 7(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
61	Terrestrial Biota-Excretion	5(#); 18(%)	16(#); 57(%)	7(#); 25(%)	2(#); 7(%)	2(#); 7(%)	1(#); 4(%)	1(#); 4(%)	1(#); 4(%)	3(#); 11(%)	• If absorption occurs this is critical • MWCNT dose issues unknown • Very few studies in these area, often hampered by lack of widely accessible methods for quantification • Ultrafine particles and nano material distribution in biota have been conducted by phytoremediation groups.	• Analytical Techniques 1(#); 4(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 7(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 1(#); 4(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 7(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 2(#); 7(%) • Sediment 1(#); 4(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 4(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 2(#); 7(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
62	Abiotic-Absorption	2(#); 7(%)	9(#); 32(%)	17(#); 61(%)	1(#); 4(%)	1(#); 4(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 7(%)	• MWCNT dose issues unknown	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 4(%) • Sediment 1(#); 4(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 1(#); 4(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
63	Human Cancer	27(#) 96(%)	1(#) 4(%)	0(#) 0(%)	23(#) 82(%)	4(#) 14(%)	0(#) 0(%)	6(#) 21(%)	7(#) 25(%)	14(#) 50(%)	• Ev dence for DNA damage • Existing data suggesting s mi ar ties between MWCNT and asbestos • th nk there s enough ev dent to state that some MWCNTs might cause cancer under some c rcumstances ung cancer • Severa stud es nd cate that some types of MWCNTs behave n a s mi ar manner as asbestos nduc ng mesothel oma • Fu stud es on how MWCNT affects hea th have not been done. Resu ts are mixed to date. • ncomp ete data ava ab e- ana ogy to asbestos but no d rect data for MWCNT • nha ation stud es are not d rectly ava ab e for th s • Known d srupter of mitos s but tt e to no chron c exposure data to nd cate poss b e cancers • No data Tab e 5 1 • The carc nogen c endpo nt has yet to be conv nc ng y estab shed for CNT or has the ong term effects of exposure acute or chron c a though severa stud es have now nc uded onger post exposure per ods of ~6months 1yr Stud es have typ ca y focused on the use of genetica y susceptab e an ma s or have emp oyed nappropr ate assays to conv nc ng y estab sh f CNT are or are not carc nogen c or genotoxic (e.g use of the Ames test or use of short compact f bres n an ntraper tonea assay) • An ma data nd cate that cancer s poss b e based on P stud es and that the mechan sm for caus ng cancer fo ows the asbestos f ber s ze parad gm. • Want to be sure to prevent worker nha ation exposure and determine f there are ong term effects from exposure • nsuff c ent stud es d ff cu t to s mu ate ong term exposure • No chron c stud es or rea stic exposure route stud es • Lack of comp ed set of data for CA assessment.
64	Human-Non-cancer	27(#); 96(%)	1(#); 4(%)	0(#); 0(%)	18(#); 64(%)	7(#); 25(%)	2(#); 7(%)	5(#); 18(%)	11(#); 39(%)	11(#); 39(%)	• Abundant evidence for fibrosis • Clear evidence in animal studies of adverse lung effects including fibrosis from short-term and sub-chronic studies • Data documenting inflammatory response in respiratory system • There is some available data but more would be helpful. • Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Insufficient studies; Difficult to simulate long-term exposure • No data available; No data Table 5-1 • Fairly good grasp on fibrosis and potential for mesothelioma from inhalation but not much data on dermal exposures • No chronic studies, but evidence for subchronic effects at high doses • Non-cancerous endpoints such as inflammation (lung, ocular or dermal), fibrosis and granuloma formation have most typically been described in numerous studies including several highly robust studies using inhalation expsoure although the functional impact of these observations (i.e. in terms of clinical disease) is still lacking. There has ben some investigation of the role of contaminants (e.g. metals) in the elicitaion of inflammation (inhalation and dermal exposure) as well as the role of shape. There is limited information on the systemic toxicity of CNT although some studies do show potential cardiovascular as well as immunological effects. • Want to be sure to prevent worker inhalation exposure and determine if there are long term effects from exposure. • This could be important but we simply do not know at this point in time. • Studies on a range of endpoints are available in the literature which show mixed results. • Lack of compiled set of data for CA assessment.
65	Human-Reproductive/ Developmental	27(#); 96(%)	1(#); 4(%)	0(#); 0(%)	8(#); 29(%)	14(#); 50(%)	5(#); 18(%)	2(#); 7(%)	3(#); 11(%)	22(#); 79(%)	• Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Insufficient data Table 5-1 • There is some available data but more would be helpful. • Lack of appropriate animal studies with MWCNT; if MWCNT follow the paradym of other fibrous nanoscale particles, then reproductive toxicity should not be an issue. • No chronic studies • Mostly concerned with lung/mucus rather than reproductive • Further studies are required using elevant routes of exposure and dose response experiments to establish if at plausible maternal exposure levels, a significant foetal dose and effect occurs • There were only two studies on this topic. • This could be important but we simply do not know at this point in time. • Usually at higher doses than other systemic routes so address that first, then reproductive/development • Would need to enter the blood • Lack of compiled set of data for CA assessment.

ID	Element-RRF Pair	Influential Factors						
		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
63	Human Cancer	• Ana ytica Techn ques 10(#) 36(%) • Contro Techno og es 9(#) 32(%) • MWCNT Process ng Methods 8(#) 29(%) • MWCNT Pur ty 11(#) 39(%) • MWCNT Synthes s Methods 8(#) 29(%) • Persona Protective Equ pment 12(#) 43(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 10(#) 36(%) • Aggregation/Agg omeration State 17(#) 61(%) • App ed Coatings 14(#) 50(%) • B odegradab ty 13(#) 46(%) • Cata ytic Activ ty 11(#) 39(%) • Charge 10(#) 36(%) • Conductive or Magnetic Properties 3(#) 11(%) • Crysta ne Phase 6(#) 21(%) • L poph c ty 11(#) 39(%) • Matr x Bound vs Free 16(#) 57(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 17(#) 61(%) • Pers stence 15(#) 54(%) • Redox Potentia 12(#) 43(%) • S ze/S ze D str bution 16(#) 57(%) • Spec f c Surface Area 14(#) 50(%) • Structura Formu a/Mo ecu ar Structure 8(#) 29(%) • Surface Chem stry 15(#) 54(%) • Water So ub ty/D spers b ty 11(#) 39(%) • Other 2(#) 7(%) • Spec fy other 0(#) 0(%)	• A r 11(#) 39(%) • Groundwater 4(#) 14(%) • Sed ment 2(#) 7(%) • So 3(#) 11(%) • Surface Water 5(#) 18(%) • Wastewater 2(#) 7(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 4(#) 14(%) • L ght Ava ab ty 0(#) 0(%) • So Poros ty 2(#) 7(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 2(#) 7(%) • W nd 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 8(#) 29(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 9(#) 32(%) • on c Strength n Env ronment 5(#) 18(%) • L gand Concentrations n Env ronment 6(#) 21(%) • Natura Organ c Matter (NOM) 6(#) 21(%) • Other Contaminants n Env ronment 8(#) 29(%) • pH 6(#) 21(%) • Protein Concentration n Env ronment 4(#) 14(%) • Sa n ty 3(#) 11(%) • Surfactant (in Lab) 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 11(#) 39(%) • B oaccumu ation 12(#) 43(%) • B omagn f cation 6(#) 21(%) • M crob a Commun ties n Env ronment 3(#) 11(%) • Organ sm Hea th 10(#) 36(%) • Spec es/ nd v dua Developmenta Behav or 5(#) 18(%) • Spec es/ nd v dua Feed ng Behav or 7(#) 25(%) • Spec es/ nd v dua Reproductive Behav or 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 14(#) 50(%) • Chron c Exposure 19(#) 68(%) • Exposure Route 17(#) 61(%) • Geograph c Location (i.e. rura vs urban) 4(#) 14(%) • Hab tat Structure 3(#) 11(%) • Human Activ ty 11(#) 39(%) • nd v dua Activ ty Level 10(#) 36(%) • L fe Stage 10(#) 36(%) • Occupation 15(#) 54(%) • Subchron c Exposure 16(#) 57(%) • Susceptib e Popu ations/ nd v dua s 17(#) 61(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
64	Human-Non-cancer	• Analytical Techniques 8(#); 29(%) • Control Technologies 7(#); 25(%) • MWCNT Processing Methods 6(#); 21(%) • MWCNT Purity 8(#); 29(%) • MWCNT Synthesis Methods 6(#); 21(%) • Personal Protective Equipment 8(#); 29(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 10(#); 36(%) • Aggregation/Agglomeration State 12(#); 43(%) • Applied Coatings 10(#); 36(%) • Biodegradability 10(#); 36(%) • Catalytic Activity 8(#); 29(%) • Charge 8(#); 29(%) • Conductive or Magnetic Properties 3(#); 11(%) • Crystalline Phase 3(#); 11(%) • Lipophilicity 10(#); 36(%) • Matrix Bound vs. Free 11(#); 39(%) • Morphology (e.g. aspect ratio, length, width, shape) 12(#); 43(%) • Persistence 11(#); 39(%) • Redox Potential 8(#); 29(%) • Size/Size Distribution 12(#); 43(%) • Specific Surface Area 10(#); 36(%) • Structural Formula/Molecular Structure 6(#); 21(%) • Surface Chemistry 11(#); 39(%) • Water Solubility/Dispersibility 9(#); 32(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 8(#); 29(%) • Groundwater 5(#); 18(%) • Sediment 2(#); 7(%) • Soil 3(#); 11(%) • Surface Water 5(#); 18(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 3(#); 11(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 7(#); 25(%) • Dissolved Oxygen Content 2(#); 7(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 7(#); 25(%) • Ionic Strength in Environment 5(#); 18(%) • Ligand Concentrations in Environment 6(#); 21(%) • Natural Organic Matter (NOM) 5(#); 18(%) • Other Contaminants in Environment 6(#); 21(%) • pH 5(#); 18(%) • Protein Concentration in Environment 4(#); 14(%) • Salinity 3(#); 11(%) • Surfactant (in Lab) 6(#); 21(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 7(#); 25(%) • Bioaccumulation 8(#); 29(%) • Biomagnification 4(#); 14(%) • Microbial Communities in Environment 2(#); 7(%) • Organism Health 6(#); 21(%) • Species/Individual Developmental Behavior 3(#); 11(%) • Species/Individual Feeding Behavior 6(#); 21(%) • Species/Individual Reproductive Behavior 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 13(#); 46(%) • Chronic Exposure 13(#); 46(%) • Exposure Route 13(#); 46(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 3(#); 11(%) • Human Activity 6(#); 21(%) • Individual Activity Level 7(#); 25(%) • Life Stage 8(#); 29(%) • Occupation 11(#); 39(%) • Subchronic Exposure 11(#); 39(%) • Susceptible Populations/Individuals 10(#); 36(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
65	Human-Reproductive/ Developmental	• Analytical Techniques 9(#); 32(%) • Control Technologies 7(#); 25(%) • MWCNT Processing Methods 6(#); 21(%) • MWCNT Purity 9(#); 32(%) • MWCNT Synthesis Methods 6(#); 21(%) • Personal Protective Equipment 8(#); 29(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 10(#); 36(%) • Aggregation/Agglomeration State 13(#); 46(%) • Applied Coatings 12(#); 43(%) • Biodegradability 11(#); 39(%) • Catalytic Activity 10(#); 36(%) • Charge 10(#); 36(%) • Conductive or Magnetic Properties 5(#); 18(%) • Crystalline Phase 5(#); 18(%) • Lipophilicity 13(#); 46(%) • Matrix Bound vs. Free 13(#); 46(%) • Morphology (e.g. aspect ratio, length, width, shape) 14(#); 50(%) • Persistence 12(#); 43(%) • Redox Potential 11(#); 39(%) • Size/Size Distribution 13(#); 46(%) • Specific Surface Area 11(#); 39(%) • Structural Formula/Molecular Structure 9(#); 32(%) • Surface Chemistry 14(#); 50(%) • Water Solubility/Dispersibility 13(#); 46(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 6(#); 21(%) • Groundwater 5(#); 18(%) • Sediment 2(#); 7(%) • Soil 3(#); 11(%) • Surface Water 5(#); 18(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 2(#); 7(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 3(#); 11(%) • Dispersing Agents 6(#); 21(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 2(#); 7(%) • Heavy Metals in Environment 6(#); 21(%) • Ionic Strength in Environment 5(#); 18(%) • Ligand Concentrations in Environment 4(#); 14(%) • Natural Organic Matter (NOM) 4(#); 14(%) • Other Contaminants in Environment 5(#); 18(%) • pH 5(#); 18(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 11(#); 39(%) • Bioaccumulation 10(#); 36(%) • Biomagnification 7(#); 25(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 7(#); 25(%) • Species/Individual Developmental Behavior 7(#); 25(%) • Species/Individual Feeding Behavior 7(#); 25(%) • Species/Individual Reproductive Behavior 7(#); 25(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 13(#); 46(%) • Chronic Exposure 16(#); 57(%) • Exposure Route 16(#); 57(%) • Geographic Location (i.e. rural vs. urban) 4(#); 14(%) • Habitat Structure 4(#); 14(%) • Human Activity 9(#); 32(%) • Individual Activity Level 9(#); 32(%) • Life Stage 10(#); 36(%) • Occupation 11(#); 39(%) • Subchronic Exposure 13(#); 46(%) • Susceptible Populations/Individuals 15(#); 54(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
66	Aquatic Biota-Survival	13(#); 46(%)	13(#); 46(%)	2(#); 7(%)	10(#); 36(%)	3(#); 11(%)	0(#); 0(%)	2(#); 7(%)	7(#); 25(%)	4(#); 14(%)	• Existing data documenting physical effects of MWCNT • Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Very few toxicology studies available for aquatic biota. • If there are significant releases to surface water must be sure will not harm aquatic species. • Incomplete data available. • There are complexities in perfoming studies with particulates that do not generally form steady homogenous suspensions making interpretation of actual applied dose difficult and therefore the devlopment of an accurate dose-response relationship challenging. In addition, there are only limited studies available although several do exist. • Minimal effects are typically observed for sediment organisms, but various effects have been observed for water-dwelling organisms • MWCNT are highly persistent in the environment and hydrophobic, which may cause them to accumulate in food webs. If carrying hazardous pollutants they can create more concentrated source of these pollutant to env. receptors.	• Analytical Techniques 3(#); 11(%) • Control Technologies 3(#); 11(%) • MWCNT Processing Methods 4(#); 14(%) • MWCNT Purity 4(#); 14(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 21(%) • Aggregation/Agglomeration State 7(#); 25(%) • Applied Coatings 5(#); 18(%) • Biodegradability 4(#); 14(%) • Catalytic Activity 3(#); 11(%) • Charge 2(#); 7(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 7(#); 25(%) • Morphology (e.g. aspect ratio, length, width, shape) 7(#); 25(%) • Persistence 6(#); 21(%) • Redox Potential 5(#); 18(%) • Size/Size Distribution 7(#); 25(%) • Specific Surface Area 5(#); 18(%) • Structural Formula/Molecular Structure 3(#); 11(%) • Surface Chemistry 6(#); 21(%) • Water Solubility/Dispersibility 7(#); 25(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 7(%) • Groundwater 2(#); 7(%) • Sediment 5(#); 18(%) • Soil 1(#); 4(%) • Surface Water 6(#); 21(%) • Wastewater 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 3(#); 11(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 3(#); 11(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 5(#); 18(%) • Dissolved Oxygen Content 4(#); 14(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 6(#); 21(%) • Ionic Strength in Environment 4(#); 14(%) • Ligand Concentrations in Environment 5(#); 18(%) • Natural Organic Matter (NOM) 5(#); 18(%) • Other Contaminants in Environment 7(#); 25(%) • pH 4(#); 14(%) • Protein Concentration in Environment 5(#); 18(%) • Salinity 4(#); 14(%) • Surfactant (in Lab) 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 6(#); 21(%) • Bioaccumulation 6(#); 21(%) • Biomagnification 5(#); 18(%) • Microbial Communities in Environment 4(#); 14(%) • Organism Health 7(#); 25(%) • Species/Individual Developmental Behavior 3(#); 11(%) • Species/Individual Feeding Behavior 4(#); 14(%) • Species/Individual Reproductive Behavior 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 18(%) • Chronic Exposure 7(#); 25(%) • Exposure Route 5(#); 18(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 4(#); 14(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 5(#); 18(%) • Occupation 0(#); 0(%) • Subchronic Exposure 5(#); 18(%) • Susceptible Populations/Individuals 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
67	Aquatic B ota Developmenta	13(#) 46(%)	13(#) 46(%)	2(#) 7(%)	10(#) 36(%)	3(#) 11(%)	0(#) 0(%)	1(#) 4(%)	3(#) 11(%)	9(#) 32(%)	• Existing data suggesting energetics effects of nh b tion of food ass mi ation • Fu stud es on how MWCNT affects hea th have not been done. Resu ts are mixed to date. • f there are s gn f cant releases to surface water must be sure w not harm aquatic spec es • There are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t and therefore the dev opment of an accurate dose-response relationsh p cha eng ng • Very few toxico ogy stud es ava ab e for aquatic b ota • ncomp ete data ava ab e. • There are a number of stud es on the weight changes of organ sms w th time but fewer on other top cs related to development.	• Ana ytica Techn ques 4(#) 14(%) • Contro Techno og es 3(#) 11(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 5(#) 18(%) • Aggregation/Agg omeration State 6(#) 21(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 4(#) 14(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 7(#) 25(%) • Matr x Bound vs Free 7(#) 25(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 7(#) 25(%) • Pers stence 6(#) 21(%) • Redox Potentia 7(#) 25(%) • S ze/S ze D str bution 7(#) 25(%) • Spec f c Surface Area 5(#) 18(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 7(#) 25(%) • Water So ub ty/D spers b ty 7(#) 25(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 7(%) • Groundwater 2(#) 7(%) • Sed ment 5(#) 18(%) • So 1(#) 4(%) • Surface Water 6(#) 21(%) • Wastewater 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 2(#) 7(%) • Temperature 3(#) 11(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 4(#) 14(%) • D sso ved Oxygen Content 4(#) 14(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 7(#) 25(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 6(#) 21(%) • Natura Organ c Matter (NOM) 5(#) 18(%) • Other Contaminants n Env ronment 7(#) 25(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 5(#) 18(%) • Sa n ty 4(#) 14(%) • Surfactant (in Lab) 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 8(#) 29(%) • B oaccumu ation 8(#) 29(%) • B omagn f cation 7(#) 25(%) • M crob a Commun ties n Env ronment 5(#) 18(%) • Organ sm Hea th 8(#) 29(%) • Spec es/ nd v dua Developmenta Behav or 6(#) 21(%) • Spec es/ nd v dua Feed ng Behav or 4(#) 14(%) • Spec es/ nd v dua Reproductive Behav or 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 18(%) • Chron c Exposure 9(#) 32(%) • Exposure Route 7(#) 25(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 5(#) 18(%) • Human Activ ty 3(#) 11(%) • nd v dua Activ ty Level 3(#) 11(%) • L fe Stage 7(#) 25(%) • Occupation 1(#) 4(%) • Subchron c Exposure 6(#) 21(%) • Susceptib e Popu ations/ nd v dua s 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
68	Aquatic B ota Reproductive	13(#) 46(%)	13(#) 46(%)	2(#) 7(%)	9(#) 32(%)	4(#) 14(%)	0(#) 0(%)	1(#) 4(%)	3(#) 11(%)	9(#) 32(%)	• Existing data suggesting energetics effects of nh b tion of food ass mi ation • Fu stud es on how MWCNT affects hea th have not been done. Resu ts are mixed to date. • There are comp exities n perfoming stud es w th particu ates that do not genera y form steady homogenous suspens ons mak ng nterpretation of actua app ed dose d ff cu t and therefore the dev opment of an accurate dose-response relationsh p cha eng ng n add tion there are on y mited stud es ava ab e a though severa do exist. • Few stud es ava ab e on th s top c • f there are s gn f cant releases to surface water must be sure w not harm aquatic spec es • ncomp ete data ava ab e. • Very few toxico ogy stud es ava ab e for aquatic b ota	• Ana ytica Techn ques 5(#) 18(%) • Contro Techno og es 3(#) 11(%) • MWCNT Process ng Methods 3(#) 11(%) • MWCNT Pur ty 4(#) 14(%) • MWCNT Synthes s Methods 2(#) 7(%) • Persona Protective Equ pment 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 6(#) 21(%) • Aggregation/Agg omeration State 7(#) 25(%) • App ed Coatings 5(#) 18(%) • B odegradab ty 5(#) 18(%) • Cata ytic Activ ty 4(#) 14(%) • Charge 3(#) 11(%) • Conductive or Magnetic Properties 2(#) 7(%) • Crysta ne Phase 2(#) 7(%) • L poph c ty 7(#) 25(%) • Matr x Bound vs Free 8(#) 29(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 8(#) 29(%) • Pers stence 6(#) 21(%) • Redox Potentia 7(#) 25(%) • S ze/S ze D str bution 7(#) 25(%) • Spec f c Surface Area 5(#) 18(%) • Structura Formu a/Mo ecu ar Structure 4(#) 14(%) • Surface Chem stry 8(#) 29(%) • Water So ub ty/D spers b ty 8(#) 29(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 7(%) • Groundwater 2(#) 7(%) • Sed ment 6(#) 21(%) • So 1(#) 4(%) • Surface Water 7(#) 25(%) • Wastewater 4(#) 14(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 3(#) 11(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 1(#) 4(%) • So /Sed ment Fractionation 3(#) 11(%) • Temperature 3(#) 11(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 2(#) 7(%) • D spers ng Agents 5(#) 18(%) • D sso ved Oxygen Content 4(#) 14(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 7(#) 25(%) • on c Strength n Env ronment 4(#) 14(%) • L gand Concentrations n Env ronment 6(#) 21(%) • Natura Organ c Matter (NOM) 6(#) 21(%) • Other Contaminants n Env ronment 7(#) 25(%) • pH 4(#) 14(%) • Protein Concentration n Env ronment 5(#) 18(%) • Sa n ty 5(#) 18(%) • Surfactant (in Lab) 6(#) 21(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 8(#) 29(%) • B oaccumu ation 8(#) 29(%) • B omagn f cation 7(#) 25(%) • M crob a Commun ties n Env ronment 5(#) 18(%) • Organ sm Hea th 9(#) 32(%) • Spec es/ nd v dua Developmenta Behav or 5(#) 18(%) • Spec es/ nd v dua Feed ng Behav or 5(#) 18(%) • Spec es/ nd v dua Reproductive Behav or 7(#) 25(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 18(%) • Chron c Exposure 10(#) 36(%) • Exposure Route 8(#) 29(%) • Geograph c Location (i.e. rura vs urban) 2(#) 7(%) • Hab tat Structure 5(#) 18(%) • Human Activ ty 3(#) 11(%) • nd v dua Activ ty Level 3(#) 11(%) • L fe Stage 8(#) 29(%) • Occupation 1(#) 4(%) • Subchron c Exposure 7(#) 25(%) • Susceptib e Popu ations/ nd v dua s 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
69	Aquatic B ota Other Sub etha Endpo nts	13(#) 46(%)	13(#) 46(%)	2(#) 7(%)	6(#) 21(%)	3(#) 11(%)	4(#) 14(%)	1(#) 4(%)	2(#) 7(%)	10(#) 36(%)	• Existing data suggesting energetics effects of nh b tion of food ass mi ation • f the organ sm cannot ve, develop or reproduce what else s there? • ncomp ete data ava ab e. • Very few toxico ogy stud es ava ab e for aquatic b ota • Few stud es ava ab e on th s top c • Poss b e endocr ne d sruptors? • The ong term mpact of sub etha effects (such as neuro og ca or behav oura changes) fee has yet to be estab shed and th s may be mportant n the ong term hea th of an aquatic ecosystem.	• Ana ytica Techn ques 2(#) 7(%) • Contro Techno og es 1(#) 4(%) • MWCNT Process ng Methods 1(#) 4(%) • MWCNT Pur ty 2(#) 7(%) • MWCNT Synthes s Methods 1(#) 4(%) • Persona Protective Equ pment 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Adsorption/Desorption Ab ty 4(#) 14(%) • Aggregation/Agg omeration State 5(#) 18(%) • App ed Coatings 3(#) 11(%) • B odegradab ty 3(#) 11(%) • Cata ytic Activ ty 2(#) 7(%) • Charge 2(#) 7(%) • Conductive or Magnetic Properties 1(#) 4(%) • Crysta ne Phase 1(#) 4(%) • L poph c ty 3(#) 11(%) • Matr x Bound vs Free 5(#) 18(%) • Morpho ogy (e.g aspect ratio ength w dth shape) 5(#) 18(%) • Pers stence 3(#) 11(%) • Redox Potentia 4(#) 14(%) • S ze/S ze D str bution 4(#) 14(%) • Spec f c Surface Area 3(#) 11(%) • Structura Formu a/Mo ecu ar Structure 3(#) 11(%) • Surface Chem stry 5(#) 18(%) • Water So ub ty/D spers b ty 5(#) 18(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#) 0(%) • Groundwater 0(#) 0(%) • Sed ment 3(#) 11(%) • So 0(#) 0(%) • Surface Water 4(#) 14(%) • Wastewater 1(#) 4(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• F ow Regime 2(#) 7(%) • L ght Ava ab ty 1(#) 4(%) • So Poros ty 0(#) 0(%) • So /Sed ment Fractionation 1(#) 4(%) • Temperature 2(#) 7(%) • W nd 0(#) 0(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Conductiv ty 1(#) 4(%) • D spers ng Agents 2(#) 7(%) • D sso ved Oxygen Content 2(#) 7(%) • Exposure to Sun ght 1(#) 4(%) • Heavy Meta s n Env ronment 4(#) 14(%) • on c Strength n Env ronment 1(#) 4(%) • L gand Concentrations n Env ronment 3(#) 11(%) • Natura Organ c Matter (NOM) 3(#) 11(%) • Other Contaminants n Env ronment 4(#) 14(%) • pH 2(#) 7(%) • Protein Concentration n Env ronment 2(#) 7(%) • Sa n ty 2(#) 7(%) • Surfactant (in Lab) 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 14(%) • B oaccumu ation 4(#) 14(%) • B omagn f cation 3(#) 11(%) • M crob a Commun ties n Env ronment 2(#) 7(%) • Organ sm Hea th 6(#) 21(%) • Spec es/ nd v dua Developmenta Behav or 3(#) 11(%) • Spec es/ nd v dua Feed ng Behav or 3(#) 11(%) • Spec es/ nd v dua Reproductive Behav or 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 7(%) • Chron c Exposure 6(#) 21(%) • Exposure Route 4(#) 14(%) • Geograph c Location (i.e. rura vs urban) 1(#) 4(%) • Hab tat Structure 1(#) 4(%) • Human Activ ty 2(#) 7(%) • nd v dua Activ ty Level 2(#) 7(%) • L fe Stage 4(#) 14(%) • Occupation 1(#) 4(%) • Subchron c Exposure 4(#) 14(%) • Susceptib e Popu ations/ nd v dua s 3(#) 11(%) • Other 0(#) 0(%) • Spec fy other 0(#) 0(%)
70	Terrestrial Biota-Survival	9(#); 32(%)	17(#); 61(%)	2(#); 7(%)	5(#); 18(%)	4(#); 14(%)	0(#); 0(%)	0(#); 0(%)	4(#); 14(%)	5(#); 18(%)	• Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Incomplete data available. • One lab study was identified that determined tissue concentrations of MWCMTs in earthworms exposed to MWCMTs via soil for 30 days. We know that high persistence and hydrophobicity generally lead to bioaccumulation. • Very few toxicology studies available for terrestrial biota • There have been a number of plant studies which show toxic effects at high concentrations and a lack of mortality in earthworm studies but decreased survival with some microorganism studies. • Survival data available is not specific for MWNT exposure.	• Analytical Techniques 3(#); 11(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 14(%) • Aggregation/Agglomeration State 4(#); 14(%) • Applied Coatings 3(#); 11(%) • Biodegradability 4(#); 14(%) • Catalytic Activity 3(#); 11(%) • Charge 3(#); 11(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 2(#); 7(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 4(#); 14(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 14(%) • Persistence 4(#); 14(%) • Redox Potential 4(#); 14(%) • Size/Size Distribution 4(#); 14(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 4(#); 14(%) • Water Solubility/Dispersibility 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 1(#); 4(%) • Sediment 2(#); 7(%) • Soil 4(#); 14(%) • Surface Water 4(#); 14(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 1(#); 4(%) • Soil Porosity 3(#); 11(%) • Soil/Sediment Fractionation 3(#); 11(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 2(#); 7(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 4(#); 14(%) • Ionic Strength in Environment 3(#); 11(%) • Ligand Concentrations in Environment 3(#); 11(%) • Natural Organic Matter (NOM) 4(#); 14(%) • Other Contaminants in Environment 4(#); 14(%) • pH 3(#); 11(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 18(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 5(#); 18(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 4(#); 14(%) • Species/Individual Developmental Behavior 2(#); 7(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 11(%) • Chronic Exposure 5(#); 18(%) • Exposure Route 5(#); 18(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 4(#); 14(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 3(#); 11(%) • Occupation 0(#); 0(%) • Subchronic Exposure 3(#); 11(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
71	Terrestrial Biota-Developmental	9(#); 32(%)	17(#); 61(%)	2(#); 7(%)	6(#); 21(%)	3(#); 11(%)	0(#); 0(%)	0(#); 0(%)	3(#); 11(%)	6(#); 21(%)	• Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Incomplete data available. • Very few toxicology studies available for terrestrial biota. • There are some studies on this with plant growth and root and shoot length, but fewer studies on other organisms except for one study on bacteria in soils. • Survival data available is not specific for MWNT exposure.	• Analytical Techniques 3(#); 11(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 14(%) • Aggregation/Agglomeration State 4(#); 14(%) • Applied Coatings 3(#); 11(%) • Biodegradability 4(#); 14(%) • Catalytic Activity 3(#); 11(%) • Charge 3(#); 11(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 2(#); 7(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 4(#); 14(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 14(%) • Persistence 4(#); 14(%) • Redox Potential 4(#); 14(%) • Size/Size Distribution 4(#); 14(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 4(#); 14(%) • Water Solubility/Dispersibility 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 1(#); 4(%) • Sediment 2(#); 7(%) • Soil 4(#); 14(%) • Surface Water 4(#); 14(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 1(#); 4(%) • Soil Porosity 3(#); 11(%) • Soil/Sediment Fractionation 3(#); 11(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 2(#); 7(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 4(#); 14(%) • Ionic Strength in Environment 3(#); 11(%) • Ligand Concentrations in Environment 3(#); 11(%) • Natural Organic Matter (NOM) 4(#); 14(%) • Other Contaminants in Environment 4(#); 14(%) • pH 3(#); 11(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 18(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 5(#); 18(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 4(#); 14(%) • Species/Individual Developmental Behavior 3(#); 11(%) • Species/Individual Feeding Behavior 2(#); 7(%) • Species/Individual Reproductive Behavior 3(#); 11(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 11(%) • Chronic Exposure 5(#); 18(%) • Exposure Route 5(#); 18(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 4(#); 14(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 3(#); 11(%) • Occupation 0(#); 0(%) • Subchronic Exposure 3(#); 11(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
72	Terrestrial Biota-Reproductive	9(#); 32(%)	17(#); 61(%)	2(#); 7(%)	5(#); 18(%)	4(#); 14(%)	0(#); 0(%)	0(#); 0(%)	2(#); 7(%)	7(#); 25(%)	• Full studies on how MWCNT affects health have not been done. Results are mixed to date. • Few studies are available on this topic. • Incomplete data available. • Very few toxicology studies available for terrestrial. • Survival data available is not specific for MWNT exposure.	• Analytical Techniques 4(#); 14(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 18(%) • Aggregation/Agglomeration State 5(#); 18(%) • Applied Coatings 3(#); 11(%) • Biodegradability 5(#); 18(%) • Catalytic Activity 3(#); 11(%) • Charge 3(#); 11(%) • Conductive or Magnetic Properties 2(#); 7(%) • Crystalline Phase 2(#); 7(%) • Lipophilicity 5(#); 18(%) • Matrix Bound vs. Free 5(#); 18(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 18(%) • Persistence 4(#); 14(%) • Redox Potential 4(#); 14(%) • Size/Size Distribution 4(#); 14(%) • Specific Surface Area 2(#); 7(%) • Structural Formula/Molecular Structure 2(#); 7(%) • Surface Chemistry 5(#); 18(%) • Water Solubility/Dispersibility 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 14(%) • Groundwater 1(#); 4(%) • Sediment 3(#); 11(%) • Soil 4(#); 14(%) • Surface Water 5(#); 18(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 7(%) • Light Availability 1(#); 4(%) • Soil Porosity 3(#); 11(%) • Soil/Sediment Fractionation 4(#); 14(%) • Temperature 2(#); 7(%) • Wind 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 7(%) • Dispersing Agents 3(#); 11(%) • Dissolved Oxygen Content 2(#); 7(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 4(#); 14(%) • Ionic Strength in Environment 3(#); 11(%) • Ligand Concentrations in Environment 3(#); 11(%) • Natural Organic Matter (NOM) 5(#); 18(%) • Other Contaminants in Environment 4(#); 14(%) • pH 3(#); 11(%) • Protein Concentration in Environment 3(#); 11(%) • Salinity 2(#); 7(%) • Surfactant (in Lab) 4(#); 14(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 5(#); 18(%) • Bioaccumulation 5(#); 18(%) • Biomagnification 5(#); 18(%) • Microbial Communities in Environment 3(#); 11(%) • Organism Health 5(#); 18(%) • Species/Individual Developmental Behavior 3(#); 11(%) • Species/Individual Feeding Behavior 3(#); 11(%) • Species/Individual Reproductive Behavior 5(#); 18(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 11(%) • Chronic Exposure 6(#); 21(%) • Exposure Route 5(#); 18(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 4(#); 14(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 4(#); 14(%) • Occupation 0(#); 0(%) • Subchronic Exposure 4(#); 14(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
73	Terrestrial Biota-Other Sublethal Endpoints	9(#); 32(%)	17(#); 61(%)	2(#); 7(%)	4(#); 14(%)	2(#); 7(%)	3(#); 11(%)	0(#); 0(%)	1(#); 4(%)	8(#); 29(%)	• If the organism cannot live, develop, or reproduce - what else is there? • Incomplete data available. • Few studies are available on this topic. • Very few toxicology studies available for terrestrial biota. • Survival data available is not specific for MWNT exposure.	• Analytical Techniques 2(#); 7(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 7(%) • Aggregation/Agglomeration State 2(#); 7(%) • Applied Coatings 1(#); 4(%) • Biodegradability 2(#); 7(%) • Catalytic Activity 1(#); 4(%) • Charge 1(#); 4(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 1(#); 4(%) • Lipophilicity 1(#); 4(%) • Matrix Bound vs. Free 2(#); 7(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 7(%) • Persistence 1(#); 4(%) • Redox Potential 1(#); 4(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 2(#); 7(%) • Water Solubility/Dispersibility 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 0(#); 0(%) • Sediment 2(#); 7(%) • Soil 1(#); 4(%) • Surface Water 2(#); 7(%) • Wastewater 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 1(#); 4(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 1(#); 4(%) • Wind 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 1(#); 4(%) • Exposure to Sunlight 1(#); 4(%) • Heavy Metals in Environment 1(#); 4(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 2(#); 7(%) • Other Contaminants in Environment 1(#); 4(%) • pH 1(#); 4(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 4(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 4(%) • Bioaccumulation 1(#); 4(%) • Biomagnification 1(#); 4(%) • Microbial Communities in Environment 1(#); 4(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 1(#); 4(%) • Habitat Structure 1(#); 4(%) • Human Activity 1(#); 4(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 0(#); 0(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
74	Other-Economic	7(#); 25(%)	11(#); 39(%)	10(#); 36(%)	2(#); 7(%)	4(#); 14(%)	1(#); 4(%)	0(#); 0(%)	3(#); 11(%)	4(#); 14(%)	• Cost benefit analyses for some applications known, but completely unknown for this application, especially since it is still not clear whether or not MWCNT will ever be used in this application. • Incomplete information available about the process and material to be pursued. • The safe use of MWCNT is important to the development of new and improved technologies in electronics, polymer composites, medicine. • Potential for rebound effects to impact the broader economy.	• Analytical Techniques 0(#); 0(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 2(#); 7(%) • MWCNT Purity 2(#); 7(%) • MWCNT Synthesis Methods 2(#); 7(%) • Personal Protective Equipment 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 2(#); 7(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 4(%) • Sediment 0(#); 0(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 2(#); 7(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 7(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 4(%) • Chronic Exposure 1(#); 4(%) • Exposure Route 1(#); 4(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 2(#); 7(%) • Human Activity 2(#); 7(%) • Individual Activity Level 2(#); 7(%) • Life Stage 1(#); 4(%) • Occupation 2(#); 7(%) • Subchronic Exposure 1(#); 4(%) • Susceptible Populations/Individuals 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
75	Other-Societal	7(#); 25(%)	11(#); 39(%)	10(#); 36(%)	3(#); 11(%)	4(#); 14(%)	0(#); 0(%)	0(#); 0(%)	4(#); 14(%)	3(#); 11(%)	• Cost benefit analyses for some applications known, but completely unknown for this application, especially since it is still not clear whether or not MWCNT will ever be used in this application. • Incomplete information available about the process and material to be pursued. • A complete understanding of the potential toxicity of MWCNT is critical if the commercial use of MWCNT is to be accomplished. • Consumer acceptance, public perception of risks.	• Analytical Techniques 0(#); 0(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 1(#); 4(%) • MWCNT Purity 1(#); 4(%) • MWCNT Synthesis Methods 1(#); 4(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 4(%) • Aggregation/Agglomeration State 1(#); 4(%) • Applied Coatings 1(#); 4(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 1(#); 4(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 4(%) • Groundwater 1(#); 4(%) • Sediment 0(#); 0(%) • Soil 1(#); 4(%) • Surface Water 1(#); 4(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 4(%) • Soil/Sediment Fractionation 1(#); 4(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 4(%) • Dispersing Agents 1(#); 4(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 1(#); 4(%) • Species/Individual Feeding Behavior 1(#); 4(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 7(%) • Chronic Exposure 2(#); 7(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 2(#); 7(%) • Habitat Structure 2(#); 7(%) • Human Activity 2(#); 7(%) • Individual Activity Level 1(#); 4(%) • Life Stage 1(#); 4(%) • Occupation 2(#); 7(%) • Subchronic Exposure 2(#); 7(%) • Susceptible Populations/Individuals 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
76	Other-Environmental Resources	7(#); 25(%)	11(#); 39(%)	10(#); 36(%)	5(#); 18(%)	2(#); 7(%)	0(#); 0(%)	1(#); 4(%)	3(#); 11(%)	3(#); 11(%)	• Cost benefit analyses for some applications known, but completely unknown for this application, especially since it is still not clear whether or not MWCNT will ever be used in this application. • Incomplete information available about the process and material to be pursued. • Research is needed to characterize toxicity potential of MWCNT by the conduct of animal studies and occupational exposure assessment. Outcomes of these studies can provide a reasonable estimate of the health risk to the general population and potential impacts on the environment. • Huge resouce consumption to make MWCNT; unsure how this industry could improve effeciency in the future.	• Analytical Techniques 1(#); 4(%) • Control Technologies 2(#); 7(%) • MWCNT Processing Methods 3(#); 11(%) • MWCNT Purity 3(#); 11(%) • MWCNT Synthesis Methods 3(#); 11(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 1(#); 4(%) • Biodegradability 1(#); 4(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 4(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 4(%) • Persistence 1(#); 4(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 4(%) • Specific Surface Area 1(#); 4(%) • Structural Formula/Molecular Structure 1(#); 4(%) • Surface Chemistry 1(#); 4(%) • Water Solubility/Dispersibility 1(#); 4(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 7(%) • Groundwater 2(#); 7(%) • Sediment 2(#); 7(%) • Soil 2(#); 7(%) • Surface Water 2(#); 7(%) • Wastewater 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 4(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 7(%) • Soil/Sediment Fractionation 2(#); 7(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 3(#); 11(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 7(%) • Ionic Strength in Environment 1(#); 4(%) • Ligand Concentrations in Environment 1(#); 4(%) • Natural Organic Matter (NOM) 1(#); 4(%) • Other Contaminants in Environment 2(#); 7(%) • pH 1(#); 4(%) • Protein Concentration in Environment 1(#); 4(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 2(#); 7(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 2(#); 7(%) • Biomagnification 2(#); 7(%) • Microbial Communities in Environment 2(#); 7(%) • Organism Health 1(#); 4(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 3(#); 11(%) • Habitat Structure 2(#); 7(%) • Human Activity 2(#); 7(%) • Individual Activity Level 1(#); 4(%) • Life Stage 0(#); 0(%) • Occupation 1(#); 4(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

Appendix F
Workshop Outcomes and Results from Round 3

Appendix F: Workshop Outcomes and Results from Round 3

Contents:

Appendix F
Workshop Outcomes and Results from Round 3

1. Summary of Information Gathered During Workshop Sessions

Section F-1 provides a summary of the information gathered during the workshop. This section includes a bulleted list of summary points covered and discussed during the workshop according to the agenda (see **Appendix A**), as well as an overview of the questions posed by participants and related discussions among participants and the facilitator at the workshop. In addition to this summary information, please refer to **Appendix L** for reference to all slides presented during the workshop that can be used as supplementary material to this section.

Section F-2 provides an overview of the prioritized Element-Risk Relevant Factor (E-RRF) pairs from Round 3 results shown graphically on the detailed Comprehensive Environmental Assessment (CEA) Framework (**Figure F-2**) and the rationales for Round 3 prioritization results (**Table F-2**). Round 3 of the prioritization process took place on Day 2 of the workshop. See subsequent sections of this appendix (**Appendix F**) for detailed results from Round 3.

Day 1

1. U.S. Environmental Protection Agency (EPA) Public Information Exchange Meeting

Summary – Welcome and Introduction to CEA Framework

- Staff from EPA welcomed participants and observers to the workshop.
- EPA explained that the CEA Framework structures complex information across the product life cycle, characterizes environmental transport, transformation, exposure, and dose information in a variety of receptors (including humans, other biota and abiotic resources such as environmental resources or the built environment), and the potential impacts that such exposures and doses might have.
- The CEA Framework's structure and process help expose knowledge gaps among its constituent information areas, so as applied here to multi-walled carbon nanotube (MWCNT) technologies, it can help connect risk assessment research with decision-making processes by identifying, reviewing, and critiquing existing and needed research thoroughly by integrating perspectives from a diverse group of stakeholders. CEA Framework and process also help analyze and assess risk trade-offs and the identification of different research areas of greatest potential concern for various case studies, including this case study that involves the use of MWCNT compared to the use of other flame-retardant chemicals in flame-retardant textiles.
- The CEA MWCNT Workshop is the important keystone event for the CEA MWCNT Prioritization Process because face-to-face discussions and structured stakeholder engagement after the first two Rounds of Prioritization allow the group to digest and process the large amount of information present in the process without creating "loudest voice" domination while avoiding "group-think."

Questions from Participants

- ➢ How do the results show the attrition from Rounds 1 and 2?

   - Response from EPA: RTI will present this information during the subsequent presentations, including the use of detailed graphs and tables for participants to review after each prioritization round.
- How much information is needed for decision making? How can you sort out these questions?
   - Response from EPA: This is indeed a challenging question. This process identifies those "prioritized" areas using this prioritization process including the Importance/Confidence matrix in which research areas that have high importance and low confidence in the data are put forth as prioritized areas.
- Why was this case study chosen?
   - Response from EPA: EPA reviewed several potential options (which are outlined in the Case Study document), asked experts to review these case studies across the agency, and experts voted across different case studies.
- What perspective should the reviewers have taken when attempting to gauge risk? Would they have confidential production estimates or a researcher without this industry knowledge?
   - Response from EPA: Participants will have varying levels of information based on their own expertise, which should fall on different parts of the spectrum. These varying responses should build another spectrum of answers. This information will also vary across a variety of potential risk management scenarios (e.g., managing risk at a commercial production plant, developing federal regulations).

2. RTI Welcome

Summary – Introduction of RTI International Staff and Workshop Facilitator

- Staff from RTI International and the CEA MWCNT Workshop facilitator provided an overview of the workshop's goals and how CEA is applied to MWCNT for this and previous case studies.
- The workshop's primary goal was to generate detailed, actionable research questions about prioritized areas of the CEA Framework in the context of assessments and subsequent risk management decisions this research would support, and to generate feedback to improve the CEA prioritization process for use in emerging technologies characterized by uncertainty.
- General information about the workshop process and agenda was presented.

Questions from Participants

- Will the review of prioritization rounds and results of workshop be included in the Summary Report document?
   - Response from RTI: Yes, the workshop results will be included in the Summary Report document.

3. Review Prioritization Scores to Date

Summary

- The Workshop facilitator presented a review of the results from the two previous Rounds of Prioritization (Rounds 1 and 2).
- First, Round 1 results were presented. Round 1 results focused on the large number of E-RRF pairs (79%) that were grouped into the high importance/low confidence (highest priority; red

color) bin of the Importance/Confidence Matrix of E-RRF Pairs (i.e., "Importance" refers to importance to consider in risk assessment, and "Confidence" refers to confidence in data to support risk management decisions). CEA Level-specific results were also presented, and the five Elements with the highest amount of "Important" ratings were shown.

- Similar results were presented for Round 2, as was a brief analysis of changes in the E-RRF rating results between Round 1 and Round 2; the main change was that several more of the Product Life Cycle CEA Level's E-RRF pairs were grouped into the Importance/Confidence Matrix of E-RRF pairs in Round 2.

Questions from Participants

- How can you manage a balance between ecosystem health and human health?
  - Response from RTI: Although EPA is termed the "Environmental" Protection Agency, this case study similar to other case studies applying CEA focuses on both human health and environmental health.
- I would like to see more of the rankings rather than just the top five. Can RTI present all results from Round 1 and 2?
  - Response from RTI: Yes, we will present these results in subsequent presentations.
- Was RTI surprised about the distribution of E-RRFs over matrix?
  - Answer: RTI was not entirely surprised but anticipated a slightly more even distribution.

4. Nominal Group Technique (NGT) Instructions and NGT Process

Introduction and Instructions for the NGT Process[1]

- Each participant was given three minutes to advocate their choice for the E-RRF pair to be given high priority and to be further discussed in breakout groups.
- Each participant stated which E-RRF was important, their rationale for this, or their rationale if they agreed/disagreed with a previous participant's priority E-RRF.
- Participants were given the ability to advocate an E-RRF or support someone else's choice of a new priority.
- Participants used a star-shaped sticky note on the poster of the detailed CEA framework to advocate for their particular E-RRF pair.
- Participants used an X-shaped sticky note on the poster to state that E-RRF should not be prioritized.
- Participants were given an overview for determining which E-RRFs are selected for breakout groups.

Table F-1. Participant Identification/Mapping to Expertise and Sector Groups

Participant ID	Participant Expertise Group	Participant Sector Group
1	Ecological Effects	Independent Consultants
2	Ecological Effects	Government
3	Human Health Effects	Academic Institutions and Centers
4	Ecological Effects	Academic Institutions and Centers
5	Human Health Effects	Industry

[1] Only a portion of NGT was used in the workshop; the round robin session.

Participant ID	Participant Expertise Group	Participant Sector Group
6	Environmental Fate & Transport	Academic Institutions and Centers
7	Manufacturing	Industry
8	Human Health Effects	Independent Consultants
9	Exposure & Dose	Academic Institutions and Centers
10	Risk Assessment	Industry
11	Environmental Fate & Transport	Government
12	Material Characterization	Government
13	Human Health Effects	NGOs

Round 1 of NGT Process[2]

CEA Level – Product Life Cycle

Use

- Use – Release Rate, because risk is dependent upon release during use and better methods for quantifying and detecting engineered nanomaterials (ENMs) in the environment are needed [Participant 2].

Product Manufacturing

- Product Manufacturing – Volume, agreed with Participant 2's suggestion for the development of methods to quantify and detect ENMs, and believed that this E-RRF also needs a quantitative method [Participant 12].
- Product Manufacturing – Release Rate, because there is a lack of relevance between environmental health and safety (EHS) research and real-world ENM toxicity, characterizations, tests, etc. [Participant 5].
- Product Manufacturing – Release Rate, agreed with most of the E-RRFs mentioned in Round 1 NGT but proposed this E-RRF because of toxicity of material and exposure-related issues [Participant 9].

Material Synthesis

- Material Synthesis – Release Rate, because there is currently uncertainty with manufacturing, which could have ecological consequences. It is important to carry out tests with surfactants, not just active ingredients, to make the experiments more realistic to real-world scenarios [Participant 1].

Disposal/Recycling

- Disposal/Recycling – Release Rate, because there may be the potential to recycle ENMs, and there could be a significant impact from doing so [Participant 13].
- Disposal/Recycling – Release Rate, because there is a need to look at disposal, characterization of ENMs, and how they are released into the environment. Many companies do not have a disposal plan and research needs to be done on how ENMs can be disposed of in an environmentally conscious way [Participant 11].

CEA Level – Environmental Transport, Transformation & Fate

Wastewater

- Wastewater – Mobility, because it is important to know the effect of carbon nanotubes (CNTs) on wastewater processes and the mobility of CNTs in wastewater. It is also important to know what is coming out of wastewater treatment plants and

[2] Note that these are grouped according to the areas of the CEA Framework rather than in chronological order, for example.

what is getting into the environment. This was prioritized in the previous round [Participant 6].

- Wastewater – Persistence, because there is concern about persistence across many environmental matrices [Participant 8].

CEA Level – Exposure Route

Human: Occupational

- Human: Occupational – Inhalation, because it has the highest risk, greatest danger, and is the most important problem [Participant 7].

Human: General Population

- Human: General Population – Dermal, because these ENMs may be released into houses with a potential to harm children crawling on floors. If one can determine the dermal aspects, then one could understand other relevant research areas as well [Participant 10].

Human: Consumer

- Human: Consumer – Inhalation, agreed with Participant 10 and Participant 7 on their E-RRFs because inhalation is important, particularly occupational risks. Selected this E-RRF because the ENM may be persistent and we need to know how upholstery exposure affects consumers [Participant 3].

CEA Level – Impacts

Aquatic Biota

- Aquatic Biota – Sub-Lethal Effects (did not pick one RRF but rather three, including Survival, Developmental, Reproductive), selected these because currently there is so little known about these three areas and they should be studied more extensively. Current data show reduced reproduction and researchers should look here for aquatic and other environmental impacts [Participant 4].

Break for Questions

- ➢ Clarification question about release rate versus volume from participants.
- ➢ Question about exposure from upholstery and dermal penetration, question of abrasion.
  - o Facilitator clarifies what is meant by "release rate."
- ➢ Reminder from facilitator about goals of workshop.
- ➢ Participants reflect that they can influence each other's views of prioritization, and struggle with prioritizing just one or two E-RRFs. They also struggle with prioritizing certain research areas that may or may not be on the detailed CEA framework.

Round 2 of NGT Process

CEA Level – Product Life Cycle

Material Processing

- Material Processing – Release Rate, agreed with Participant 1 on his E-RRF and the rationale for its inclusion [Participant 7].

Use

- Use – Volume, because the products will be used in an indoor environment for 50 to 100 years [Participant 8].

CEA Level – Environmental Transport, Transformation & Fate

Air

- Air – Persistence, because we need to think about the broader implications and other consequences caused by indirect effects from decabromodiphenyl ether (decaBDE) [Participant 6].

- Air – Persistence, because there is a general consensus that this ENM does not cause cancer and there is a concentration effect instead of an intrinsic effect. We need to study this E-RRF because there are no definitive answers [Participant 9].

Wastewater

- Wastewater – Mobility, because wastewater is the most likely route into the environment, and because there have been studies showing that there is little absorption into multi-celled organisms [Participant 2].
- Wastewater – Mobility, because we need to research, if when ENMs are out of wastewater, they can go into sediment or soil. We need to determine how ENMs first get out of the wastewater stream and how to prevent this [Participant 1].

Sediment

- Sediment – Persistence, because so far research has been looking at pristine materials and we have not looked at transformations in the environment. We need to determine if ENMs can affect bioavailability of the contaminant or what they absorb and the interactions between microbes and soil [Participant 4].
- Sediment – Persistence, because wastewater is an important pathway. These ENMs will be transported and sediments are depository for these contaminants; therefore, sediments and soils can become another carrier [Participant 11].

CEA Level – Exposure Route

Human: Occupational

- Human: Occupational – Inhalation, because we need to know how to limit exposure in a manufacturing environment, and we need to get a human risk assessment for the general population [Participant 5].

CEA Level – Dose (Kinetics)

Human

- Human – Absorption, because we need to know the effects from releases and exposures. We need to research if the ENMs are bioavailable or if they just pass through human systems [Participant 10].

CEA Level – Impacts

Human

- Human – Cancer, because of the lack of cancer studies done on inhalation exposure, particularly occupational exposures [Participant 12].
- Human – Non-Cancer, because CNT studies are currently very clear for fibrosis but there is no evidence of mesothelioma, and this is a topic that needs to be explored in the future [Participant 3].

Other

- Other – Societal, because we would like to keep the bigger picture open to discussion and deliberate on what can happen on a bigger scale [Participant 13].

Round 3 of NGT Process

CEA Level – Product Life Cycle

Material Processing

- Material Processing – Volume, because depending on the application of the product, there is a great opportunity for exposure [Participant 8].

CEA Level – Environmental Transport, Transformation & Fate

Soil

- Soil – Bioavailability, because of concern about bioavailability in dusts and soils [Participant 12].
- Soil – Bioavailability, because there is concern about the potential bioavailability in soil [Participant 10].

CEA Level – Exposure Route

Human: Occupational

- Human: Occupational – Inhalation, because there is a lot of potential with nanotechnology and we would advocate a need for more precaution. Selected E-RRF because of the potential exposure to humans including children [Participant 13].

CEA Level – Dose (Kinetics)

Human

- Human – Metabolism, agreed with Human Impact E-RRFs (cancer, non-cancer, reproductive/developmental), Human: Occupational – Inhalation, and Human: Consumer – Inhalation for adults and Ingestion for children, but advocated for this E-RRF [Participant 9].

Aquatic Biota

- Aquatic Biota – Excretion, because it is important to study how the ENMs pass through organisms [Participant 4].

CEA Level – Impacts

Human

- Human – Non-Cancer, agreed with previous E-RRFs in the wastewater element, in that ENMs will drop down in sludge and proposes that ENM exposure to farmland is minimal. He believed that ENMs from wastewater will not get into the environment, so he advocated for this E-RRF [Participant 5].
- Human – Reproductive/Developmental, because there is concern about the long-term effects of ENMs [Participant 11].
- Human – Reproductive/Developmental, because there have been studies showing a tremendous effect on reproduction of animals [Participant 7].

Aquatic Biota

- Aquatic Biota – Developmental, because a few studies could go a long way to understand chronic effects of ENMs [Participant 2].

Terrestrial Biota

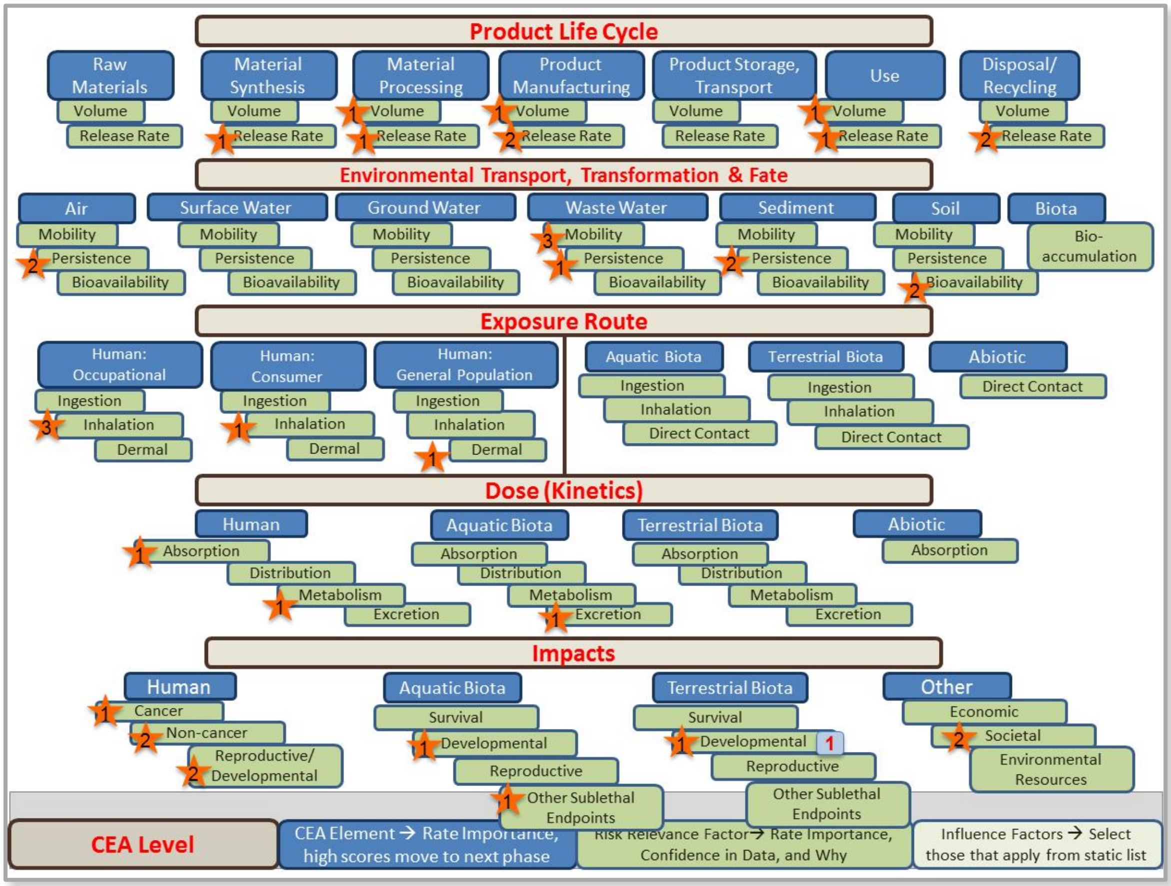
- Terrestrial Biota – Developmental, because there needs to be research on the adverse effects to find the beneficial effects [Participant 6].
- Terrestrial Biota – Developmental (should not be prioritized), agreed with Other – Societal E-RRFs and Human – Developmental, but disagreed with this E-RRF, and believed that it should not be prioritized [Participant 3]. [Participant then used another X-shaped sticky note to propose that an E-RRF should not be prioritized.]

Other

- Other – Societal, because there are consequences of nanotechnology that need more focus that have not been researched yet. Need to start looking at the holistic dynamic of societies [Participant 1]

Figure F-1 shows an overview of the outcomes of the NGT (Round Robin) process in which the participants advocated for or against E-RRF pairs. This figure is also shown in preceding sections of the report (**Figure 10** in **Section 3**).

Figure F-1. Prioritized E-RRF pairs from NGT process during workshop, shown graphically on the detailed CEA framework.



Note that numbers within the star-shaped symbols represent the number of E-RRFs proposed for prioritization by participants during the NGT process, whereas the number in the square-shaped symbol represents the number of E-RRFs proposed for exclusion from prioritization by one participant.

5. Demonstration of CEA Pilot Project by EPA[3]

- EPA presented a preview of a Web-enabled tool that allows Web site users to participate in CEA prioritization processes online, which will allow remote stakeholders to participate in the process together. An overview of the pilot process for the Web site with a diverse group of 13 participants was given, along with a look at the Web interface's design and how participants would use it to contribute to a round of prioritization.

[3] EPA was invited by RTI to present the CEA Pilot Project.

Questions from Participants

- Question from participant about inclusion of areas in CEA and explanation/review of what areas were represented in CEA:
  - Response from EPA: Brief review of logic behind CEA framework and its development.
- Questions from participant about the utility of CEA Web-enabled tool in scope of risk assessment, and use of results from CEA in risk assessment–risk management continuum:
  - Response from EPA: A web-enabled tool will be further developed in subsequent work in order to be more user-friendly and enable the link between research and risk assessment, risk management, and decision support.
- Question from participant regarding prioritization of research areas; the process of ranking vs. ratings:
  - Response from EPA and RTI: Clarification of the prioritization process, in that this process relies on participant ratings rather than direct rankings.

Day 2

<u>6. Feedback from Participants on Process</u>

- In regards to the CEA MWCNT Prioritization Process, several participants indicated that the smaller group size at the workshop (13) was positive. Some participants also indicated the need to add the question "Do you see any unexpected consequences?" to the list of Charge Questions issued by EPA.
- In regards to the CEA MWCNT Prioritization Tool (the spreadsheet-based tool used by participants to complete the prioritization rounds), several participants expressed the fact that the Tool was not user-friendly due to graphical interface limitations and inconveniences. In particular, participants expressed the fact that it was difficult to see the entire rating process at one time and therefore, some pieces could be easily missed.
- In regards to other materials developed for the process, several of the participants indicated that the Webinar to introduce participants to the process was informative and effective, although it could have been hosted at a later time of day to accommodate West Coast participants.
- In regards to the rounds of prioritization, some participants felt that the third round of prioritization was easy to perform quickly and was a fruitful pursuit because a clearer set of goals (those of the workshop) helped frame the activity, whereas others felt under pressure while completing it and found it superfluous. Some participants realized this was an iterative process but felt that we were not moving forward, and they suggested that the process could have kept narrowing the focus with each round. In addition, for the prioritization rounds, some participants suggested the need for an unstructured Round 0, and asked outright "What do you think the problems are?" as a kind of calibration to get a general idea of the participants' knowledge in the field and possibly uncover "nuggets" of missed information. Overall, some participants felt there was too much structure to CEA.
- Also in regards to the prioritization process, some participants mentioned that the prioritization results could have been reported in a simpler, more approachable form that exposed extreme outliers in participant choices. One participant indicated that one of the problems with results reporting is about taking a multidimensional problem and projecting it onto a 2-dimensional report/table/spreadsheet and expressed concern that there needs to be a filter to make the complex information useful, such as an interface (likely Web-based) that takes advantage of mind-mapping approaches or other methods for non-linear analysis. Other participants felt a lot of the influential factors were important, although the process did not necessarily reveal how they were important. Some participants indicated that there are a lot of data that have not been captured in the first spreadsheet rounds, and suggested an inquiry with statistical tools.
- Some participants expressed difficulty in prioritizing research areas because they felt that there

are actually several/many important areas that we do not know much about and felt that they prioritized many things as important. In regards to the prioritization process, some participants expressed the need to know the definitions and terms used in the prioritization process such as mobility and persistence, etc.

- Other participants expressed that they were actually not frustrated with the process, but they expressed that they thought it did cater more toward certain individuals rather than others; hence, the process was not ideal for a wide range of stakeholders. This participant suggested the process needs to be grounded within a broader spectrum for the bigger underlying questions to be addressed. They suggested that input rather could be translated/fed into the process instead of using a spreadsheet. Furthermore, this participant indicated that ethical/moral structure was not easily represented in a spreadsheet. They also indicated that NGT was a very useful process, but the value of that process was lost on Round 3 because it did not translate and the values fell short. The participant recommended that the organizers should give three copies of detailed framework and let participants highlight their top 5 and top 10 E-RRFs, which could be a better practice for face-to-face meetings.
- Some participants suggested a break for approximately 10 minutes between Round Robin rounds to collect thoughts and look back at the case study. They also suggested that a little more discussion in Round Robin sessions as well as time for questions would be beneficial. A few participants felt that the NGT process could have continued for a few more rounds. With this feedback, several participants indicated that they would have preferred a finite number of votes after the Round Robin session.

7. Review of Prioritization Results from Day 1

Overview of the Results of Round 3 – Summary

- The workshop facilitator presented a review of the results from the final round of prioritization (Round 3).
- Results show that a large majority of the E-RRFs on the Prioritization Matrix were grouped into the highest priority (i.e., red) bin (26/39 E-RRFs or 69%).
- All CEA Levels were within this highest priority (i.e., red) bin.
- Overview of changes between Round 2 and Round 3 (i.e., overall decrease in E-RRFs binned in highest priority bin).
- Results indicated that top 15 E-RRFs match up with results from NGT process and Round 3 results.

Participant Discussion/Questions about Results of Round 3

- Participants felt that some of the changes might just be the mix of people and their backgrounds.
  - Response by facilitator: This mix is by design, through the elevation of your areas of expertise and subset of interests.
- One participant inquired about the fact that an E-RRF with cancer did not make it to the top 15 E-RRFs, and therefore wanted to clarify if they could continue discussing this E-RRF at the workshop.
  - Response by facilitator: Human – Cancer will not be addressed in breakout groups because it was not included in the 15 most elevated E-RRFs.
- One participant suggested the need to split out the top 5 and top 10 E-RRFs. There are already some cancer studies for humans but none for non-cancer studies.
  - Response by facilitator: The confidence in the state of the data may have caused people to put non-cancer as a prioritized research area.

- One participant indicated that they would like to see the actual score for each E-RRF, since they believed that would be helpful.
- Another participant commented that they would like to have flexibility in the process because depending on expertise, the weight for each question could be different. We should be able to have flexibility to discuss anything that pops out.
- One participant requested more information about absorption, distribution, metabolism, and excretion (ADME), in regards to it being one process, but here it is three things.
    - Response by facilitator: We have not achieved equal granularity everywhere on the CEA framework based on expertise.
- One participant did not think the spreadsheet captured the discussion from NGT process well and would have liked to return to the board to see the 15 E-RRFs that were later prioritized.
    - Response by facilitator: This is a rating process, not a voting process. This is the transparent result of that which is based on individual opinions. Furthermore, a review of the similarities and differences between the outcome of the NGT process and the prioritization rounds, particularly Round 3, was presented earlier at the workshop.

8. Introduce Goals of Research Question Development

- The workshop facilitator introduced the purpose of the participant breakout groups, which aim to develop specific actionable research questions for the 15 most agreed-upon, prioritized 15 E-RRF pairs identified by Round 3. The facilitator also provided a review of participants' roles to collectively identify priority research gaps to support assessments that inform risk management decisions, and reviewed the link between research and risk management. Participants were introduced to the breakout group template and were given instructions for completing it.

9. Form Breakout Groups

- Participants were assigned to breakout groups and associated E-RRFs.
- Participants were given an overview of assigning identified E-RRFs for each breakout group.

10. Breakout Group Work

The following lists provide an overview of the topics discussed within each breakout group as they completed their breakout group template for their assigned E-RRFs. (See **Appendix J** for all materials and reporting from the breakout groups. See **Appendix L** for the slides presented by the breakout groups, along with all slides of the workshop.)

Breakout Group 1: There was discussion on the following parameters and factors:

- Co-factors in deposition of MWCNT
- Developing data for non-cancer impacts
- Approximating the material used in upholstery application
- Scenarios for their particular E-RRF pair
- Discussion of relevant literature studies of MWCNT
- Studies relevant to co-factors, in particular, deposition of MWCNT
- Animal studies that would be most appropriate
- Available methods to detect excretion byproducts
- Methods to detect MWCNT in the body
- Different methods for tracers
- Cost and time frames of different methods

- Aspects of human metabolism
- Occupational exposure assessment
- Order of completion: informing assessment vs. what research is needed to inform assessment
- Raw MWCNT with material-related MWCNT
- Use of in vitro methods to develop analytical techniques to measure metabolism rate and future forms

Breakout Group 2: There was discussion on the following parameters and factors:

- Aggregation vs. persistence
- Chemical/physical properties that promote aggregation of ENMs
- Potential reactivation of aggregates and re-suspension in air
- Reducing atmospheric residence time and ways to track residence time
- Particle size and which particles lead to adverse health effects
- Biological, physical, and chemical characterization of ENMs
- Moratoriums on disposal and recycling
- Measuring the atmospheric mobility of MWCNT
- More rigorous monitoring as a risk management decision
- Varying occupational hygiene requirements vs. the general public
- Physiochemical properties that may increase likelihood of absorption
- Research to determine particle properties that influence absorption

Breakout Group 3: There was discussion on the following parameters and factors:

- Factors influencing specific research parameters of MWCNT
- Questions of persistence of MWCNT in different media
- Loadings in MWCNT in different fabrics
- Need more information on kinetics and degradation rate modeling
- Need more stringent regulations and mandating removal rates for processes
- Combination of natural and enhanced sediment and the speed of degradation
- Settling rates of fiber CNT
- Developing a model to predict residence time in relation to particulate size, also taking into account techniques and instrumentation use.
- Mandating/regulating the removal efficiencies in wastewater. Are CNT released from fabrics in sediment?
- How research enables assessment of mobility, persistence, and bioavailability as CNT transform

Breakout Group 4: There was discussion on the following parameters and factors:

- Range of risk management factors for different media
- Parameters important for human exposure in different media
- Various parameters that influence dermal exposure to humans
- Risk management strategies to reduce exposures
- Validation of parameters
- Surfactants
- What functionalization does to the release rate of MWCNT
- Release mechanisms
- Studying the effects of different coating methods

- Industrial material processing releases into wastewater
- Treating acid waste and organic waste independently
- Handling raw CNT to avoid releases into air
- Researching size distribution of an airborne particle and characterizing product sizes
- Needing more environmentally friendly purification methods for CNT

Day 3

11. Breakout Group Reports

Introduction by RTI

- Workshop staff reviewed the scope of the CEA Framework, relevant terms (“Element,” “Risk Relevance Factor,” “Influential Factor”) and the process of rating E-RRF pairs’ “Importance” and “Confidence” properties. An overview of the NGT process and Round 3 results were given, with the message that NGT results were similar to those from Round 3.
- An overview of breakout group formation and the purpose of breakout groups were given, as was an overview of the steps linking research questions to risk management for a given scenario.

Breakout Group Presentations

Breakout Group 3: See **Appendix J** for detailed breakout group reports.

- Comment from participant: CEA framework does not have analytical techniques included.
  - Response from facilitator: A former version of the framework had this across different areas, but others found it difficult or confusing.
- Discussion with participants about inclusion of analytical techniques and different needs for different research areas.
  - Response from facilitator: The development of a technology may be a completely different project, and EPA has worked previously on the CEA Framework to be as comprehensive as possible.
- Question from participant: What is known for analytical techniques for MWCNT in soil or water?
  - Response from another participant: There are some techniques available in the literature, although there are some uncertainties regarding these techniques.
- Discussion among participants regarding analytical methods to measure MWCNT in different media and systems.
- Question from participant about persistence of MWCNT in sediment, methods for persistence, and determining persistence.
  - Brief discussion among workshop participants regarding this topic.

Breakout Group 2: See **Appendix J** for detailed breakout group reports.

- Group clarified that research questions were not necessarily in order of importance; not ranked; they would want to include them all and would like to leave it to risk managers to prioritize.
- Question from a participant to clarify the difference between persistence and transformation and the role of environmental parameters in their role in mobility and persistence.
  - Discussion among participants on particle coatings.
- Question from a participant regarding occupational settings vs. outdoor settings.
  - Discussion among participants regarding occupational vs. outdoor exposures.
- Question about assessment types.

    - Group agrees that a portion of risk assessment could be exposure assessment.
- Question and discussion about methods that could be used to measure CNT.
    - Discussion about specific techniques for measuring CNT.
- Comment from a participant that having separate research questions may lead to having higher estimates for overall costs; perhaps combining some parameters would be beneficial for research strategies.
- Discussion among participants regarding what a meaningful public engagement is.
- Discussion among participants regarding the responsibility of different stakeholders to engage the public.
- Discussion among participants regarding looking at different case studies (e.g. pesticides) for communicating to public about risks and benefits.

Breakout Group 1: See **Appendix J** for detailed breakout group reports.

- Discussion among participants regarding absorption of translocation of MWCNT in different animal models.
- Discussion among participants regarding about literature relevant for absorption and translocation and metabolism of MWCNT in bodies and animal models.
- Comment from a participant who urged the group to remove No Observable Adverse Effect Level (NOAEL) and Lowest Observed Adverse Effect Level (LOAEL) from their breakout group template table. The participant stated that while these values have been used previously in risk assessments, they have been proven to be inaccurate/outdated.
- Discussion among participants about susceptible and sensitive populations for exposure to MWCNT, including children, immune-compromised individuals, and elderly.
- Question and discussion from participant about metabolism of MWCNT in different animal models; discussion of which animal models are best to use.

Breakout Group 2: See **Appendix J** for detailed breakout group reports.

- Question from participant regarding if standard protocols exist to assess aging of upholstery with CNT.
    - Response from other participants: No, there are probably some tests available but not totally applicable to CNT, although there are protocols for polymers. These tests would have to be an area of development. There are some studies with nano-composites, and some methods with Consumer Products Safety Commission, but it is not clear to what extent the literature is applicable to MWCNT.
- Comment from a participant regarding the relevance of analyzing lint and debris from around a house, for instance, to see if there are CNT in lint and dust.
- Discussion among participants about the need to capture data of MWCNT in wastewater or CNT from the air.
- Question from a participant about the clarification of air and water filtration and follow-up discussion of the literature on these aspects.
- Comment from a participant about the creation of nano-filters to detect ENMs. Participant also commented that some CNT aggregate in the process and discussed the role of filters to detect ENMs.

2. Overview of E-RRFs on Detailed CEA Framework and Rationales for Round 3 Results

Figure F-2 shows an overview of the prioritized E-RRF pairs from Round 3 results across the detailed CEA Framework.

Figure F-2. Prioritized E-RRF pairs from Round 3 results, shown graphically on the detailed CEA Framework

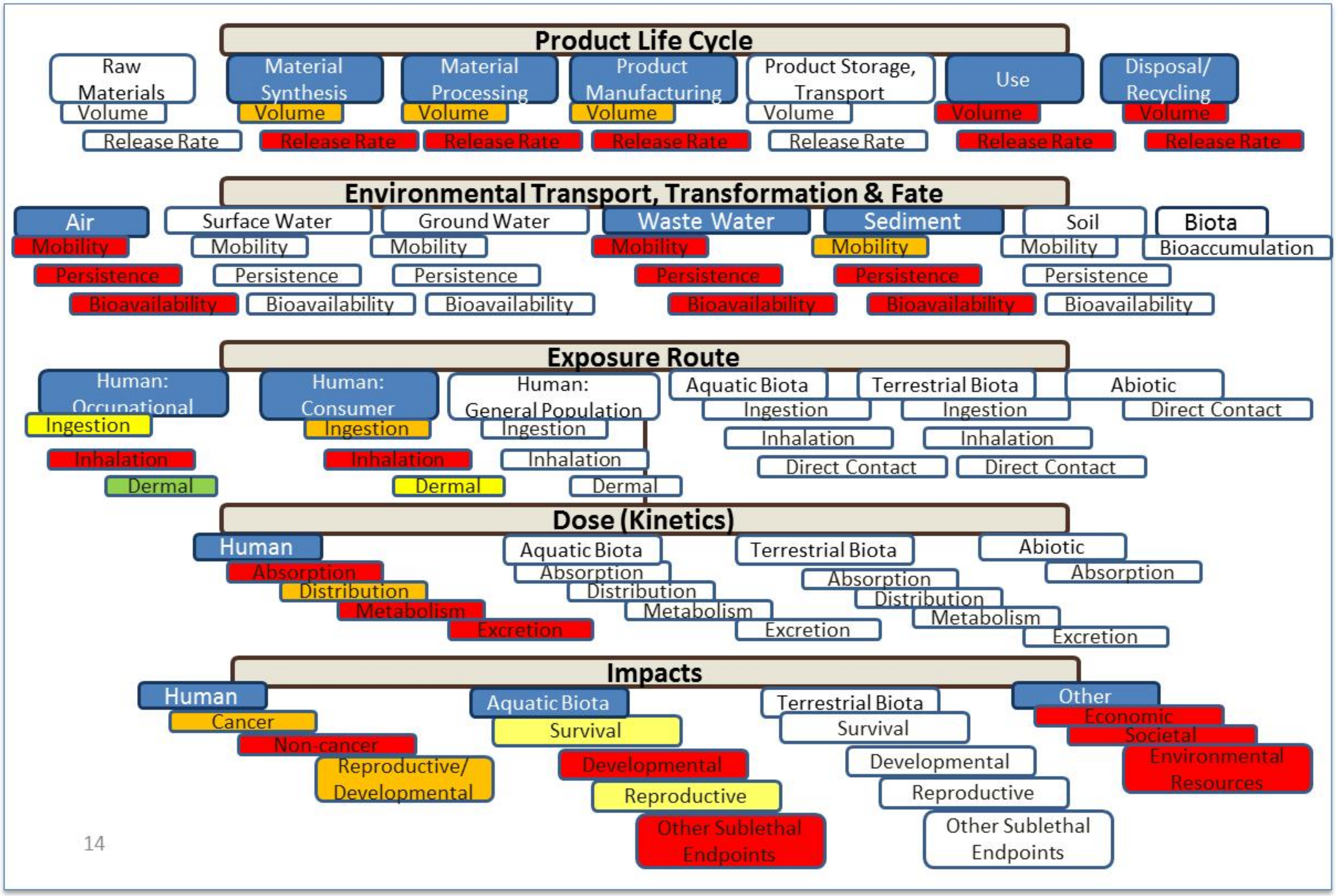


Table F-2 provides an overview of the rationales for participants' choice of research priorities from Round 3. This information provides the reasoning behind participants' prioritization of E-RRF pairs. Refer to subsequent sections in **Appendix F** for full details related to Round 3 results.

Table F-2. Reasoning for participants' choice of final research priorities (i.e., "why" responses for Round 3)

ID	Element-RRF Pair	Why	Round 3 Rank
64	Human-Non-cancer	• Insufficient data.	1
35	Human: Occupational-Inhalation	• Inhalation may be the first initial exposure occurrence with workers. • Inhalation must be controlled as inhalation exposure can cause effects. • Studies have been conducted in insects and in some animals, but the exposure routes and administration techniques have been criticized for valid reasons.	2
8	Product Manufacturing-Release Rate	• Better analytical methods are needed for carbon nanotube quantification. • Critical to determine exposure. • Not enough study.	3
16	Air-Persistence	• Known to persist. • I am not aware of studies on degradation of carbon nanotubes in air. • Insufficient data are available in this regard. • Need to know how long it may remain in the air and be available for inhalation by workers.	4
25	Wastewater-Persistence	• Unsure how structure changes. • It is unlikely that substantial degradation will occur given results in other studies. • MWCNTs appear to be persistent. • The CNT has not been observed in wastewater system in the United States. And persistence aspect of CNT in the water may need to be investigated. However, controlling nano in wastewater system is not to be believed as challenging as controlling those in the air.	5

ID	Element-RRF Pair	Why	Round 3 Rank
24	Wastewater-Mobility	• Expect releases to wastewater from manufacturing and possible washing of textiles by consumers. • The extent to which nanotubes are moved or not by wastewater treatment processes determines which environmental compartment is exposed (water or soil). Also, no studies have been conducted on this topic. • Although not many studies have been conducted in CNT in wastewater, the physicochemical characteristics of CNTs in water media have been similar to some other ultrafine and nano-materials.	6
50	Human-Absorption	• Insufficient data. • Except for inhalation route, absorption needs to occur to have an effect; if not absorbed orally or dermally, significantly reduce concerns from exposure.	7
6	Material Processing-Release Rate	• Better analytical methods are needed for carbon nanotube quantification. • Not enough data on releases from processing, envision fabric coating operations resulting in releases to environment; need to understand the form of release (matrix bound, aggregate, etc.). • Critical to determine exposure.	8
12	Use-Release Rate	• Better analytical methods are needed for carbon nanotube quantification. • This is the most important parameter for consumer exposure, but how do we realistically test the release from furniture since we are looking at long term? • We do not have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps.	9

ID	Element-RRF Pair	Why	Round 3 Rank
14	Disposal/Recycling-Release Rate	• Better analytical methods are needed for carbon nanotube quantification. It also depends upon how the recycling is performed. • Critical to determine exposure. • If waste is incinerated releases to air, if landfilled releases to water possible • Large volumes of waste may be accumulated and increase the potential for a release event. • Unsure what innovative recycling methods may evolve or what secondary products emerge. • We do not have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps.	10
15	Air-Mobility	• Insufficient data are available in this regard. • Primary route of exposure.	11
52	Human-Metabolism	• Insufficient data.	12
53	Human-Excretion	• Insufficient data.	13
13	Disposal/Recycling-Volume	• Potential for release. • Estimate based on decaBDE data. • It is unclear to what extent products will be recycled. This information is not available yet and may not be available until the products are on the market. • We do not have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps.	14
28	Sediment-Persistence	• Is persistent. • Degradation is likely to be very slow and has not been observed in some studies on uptake.	15
11	Use-Volume	• It depends on the perspective and what information is available, such as confidential information to manufacturers and EPA regulators, but little information is available for scientists and the general public. • Use volumes from decaBDE for worst-case scenario since it is a mature market. • We do not have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps.	16

ID	Element-RRF Pair	Why	Round 3 Rank
26	Wastewater-Bioavailability	• Since this E-RRF pair is persistent, we need more confidence about bioavailability. • Loadings will never lead to levels that affect wastewater treatment plant (WWTP) function. • Limited amount of study is available, although it is less relevant in fate & transport perspective. • The MWCNTs are likely to interact with the activated sludge, given results from studies with other organisms.	17
38	Human: Consumer-Inhalation	• Depends on release rate; if high enough, it could be an issue.	18
17	Air-Bioavailability	• Insufficient data are available in this regard. • Absorption across epithelial tissues has not been observed in other organisms.	19
67	Aquatic Biota-Developmental	• As seen with Environmental Dose Concentrations (EDCs), aquatic species are very sensitive and low exposures can lead to developmental effects.	20
29	Sediment-Bioavailability	• Since persistent, need more confidence about bioavailability. • Uptake has not been observed in multiple studies.	21
69	Aquatic Biota-Other Sub-lethal Endpoints	• Again, these are the effects not typically studied until environmental problems occur; need to give adequate attention.	22
75	Other-Societal		23
4	Material Synthesis-Release Rate	• No universal report mechanism is available.	24
76	Other-Environmental Resources		25
74	Other-Economic		26
63	Human-Cancer	• Insufficient data.	27

ID	Element-RRF Pair	Why	Round 3 Rank
7	Product Manufacturing-Volume	• Potential for release. • It depends on the perspective and what information is available, such as confidential information to manufacturers and EPA regulators, but little information is available for scientists and the general public. • No universal report mechanism is available. • Assume decaBDE product volumes for worst-case scenario.	28
5	Material Processing-Volume	• It depends on the perspective and what information is available, such as confidential information to manufacturers and EPA regulators, but little information is available for scientists and the general public. • Use volumes from decaBDE for worst case scenario since this is a mature market. • Potential for release.	29
65	Human-Reproductive/ Developmental	• Insufficient data.	30
51	Human-Distribution	• Insufficient data. • Distribution within tissues and specific organs could be important to determine risk.	31
37	Human: Consumer-Ingestion	• Need analytics. • Do not see much concern from ingestion of MWCNTs based on data.	32
27	Sediment-Mobility	• Sediment is the ultimate repository for environmental contaminates; material entering wastewater will eventually reside in the sediment. • The extent that MWCNTs could be redistributed into the water column during scouring events or bioturbation is unclear. • We expect it to remain in the sediment.	33
3	Material Synthesis-Volume	• Report is voluntary at this point.	34

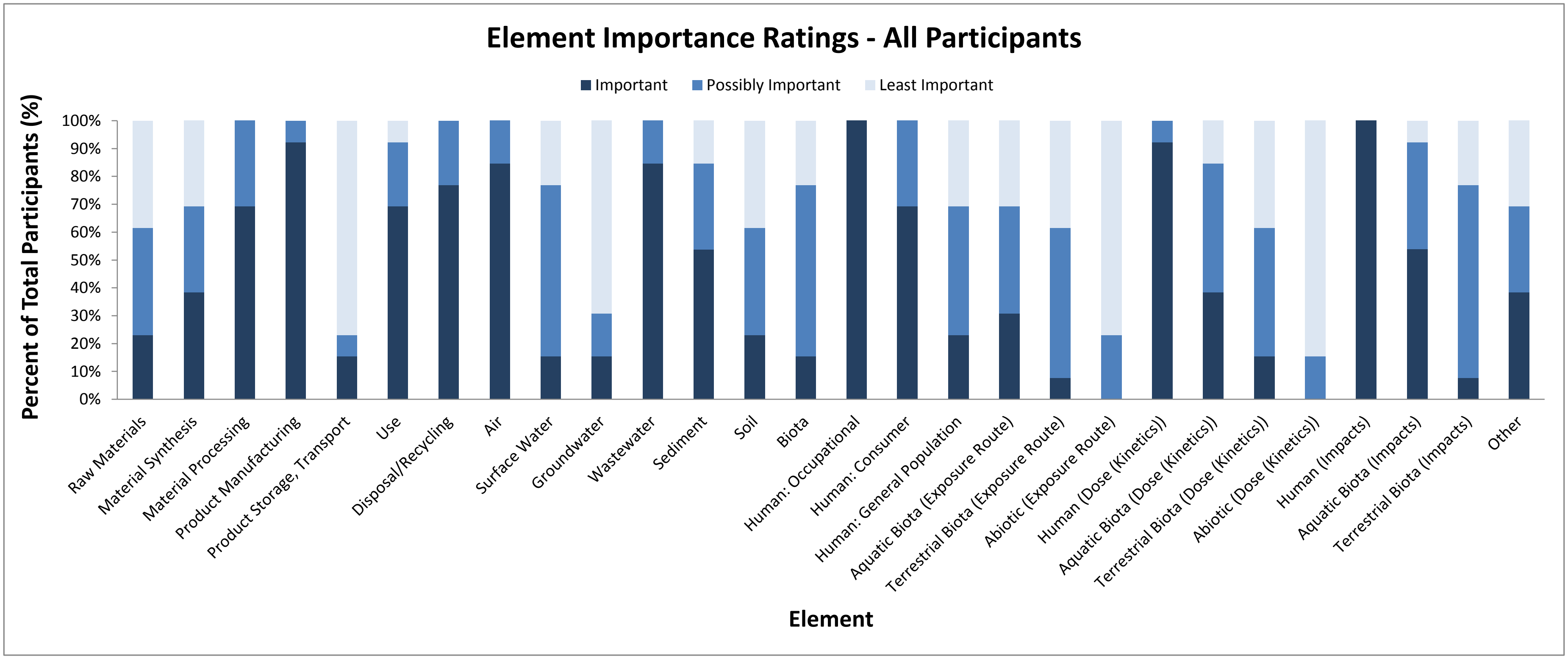
ID	Element-RRF Pair	Why	Round 3 Rank
34	Human: Occupational-Ingestion	• Do not see much concern from ingestion of MCs based on data. • There will likely be good controls to limit exposure via ingestion. • Exposure amount perspective; the relative amount of CNT intake in the form of ingestion would be much lower than inhalation in occupational settings. There are some studies presenting our luminal surfaces of GI tracts are resistant to the passage of CNTs.	35
39	Human: Consumer-Dermal	• Depends on dermal absorption rates.	36
66	Aquatic Biota-Survival	• Data do not indicate acute toxicity.	37
68	Aquatic Biota-Reproductive	• As seen with EDCs, aquatic species are very sensitive and low exposures can lead to reproductive effects.	38
36	Human: Occupational-Dermal	• In some studies using insects, dermal exposure has shown some systematic effects. However, the other routes of exposure (inhalation and ingestion) have not been completed blocked. Physicochemical properties of the CNTs known are less likely to cause a major issue on dermal exposure. • Low dermal absorption expected. • There will likely be good controls to limit dermal exposure.	39
57	Aquatic Biota-Excretion	• Depends on absorption.	40
43	Aquatic Biota-Ingestion	• Have emissions and expect to collect in sediment, which could affect aquatic species.	41
45	Aquatic Biota-Direct Contact	• Have emissions and expect to collect in sediment, which could affect aquatic species.	42
18	Surface Water-Mobility		43
31	Soil-Persistence		44
32	Soil-Bioavailability		45
19	Surface Water-Persistence		46
20	Surface Water-Bioavailability		47

ID	Element-RRF Pair	Why	Round 3 Rank
21	Groundwater-Mobility		48
41	Human: General Population-Inhalation		49
40	Human: General Population-Ingestion		50
59	Terrestrial Biota-Distribution		51
33	Biota-Bioaccumulation	• Organism uptake may occur over long periods of time (years), long-term bioaccumulation needs to be considered.	52
49	Abiotic-Direct Contact		53
62	Abiotic-Absorption		54
54	Aquatic Biota-Absorption	• Knowing whether it is absorbed by aquatic species is key for exposure.	55
2	Raw Materials-Release Rate	• Large volumes of products synthesized can result in large releases.	56
22	Groundwater-Persistence		57
23	Groundwater-Bioavailability		58
46	Terrestrial Biota-Ingestion		59
47	Terrestrial Biota-Inhalation		60
48	Terrestrial Biota-Direct Contact		61
58	Terrestrial Biota-Absorption		62
60	Terrestrial Biota-Metabolism		63

ID	Element-RRF Pair	Why	Round 3 Rank
61	Terrestrial Biota-Excretion		64
70	Terrestrial Biota-Survival		65
71	Terrestrial Biota-Developmental		66
72	Terrestrial Biota-Reproductive		67
73	Terrestrial Biota-Other Sub-lethal Endpoints		68
55	Aquatic Biota-Distribution	• Depends on absorption.	69
56	Aquatic Biota-Metabolism	• Depends on absorption.	70
30	Soil-Mobility		71
1	Raw Materials-Volume	• Important to know starting amount of material that is available for potential release.	72
10	Product Storage, Transport-Release Rate	• Estimation of release rate of particular products could be more easily tailored than the materials in previous stages, although we do not have any reliable reporting system in this regard.	73
9	Product Storage, Transport-Volume	• By the time materials are used for the production of products, manufacturers will be more aware of volume/quantity.	74
42	Human: General Population-Dermal		75
44	Aquatic Biota-Inhalation		76

Note that blank cells indicate that no participant provided a response.

2. Group Results: Element Importance Stacked Bar Chart



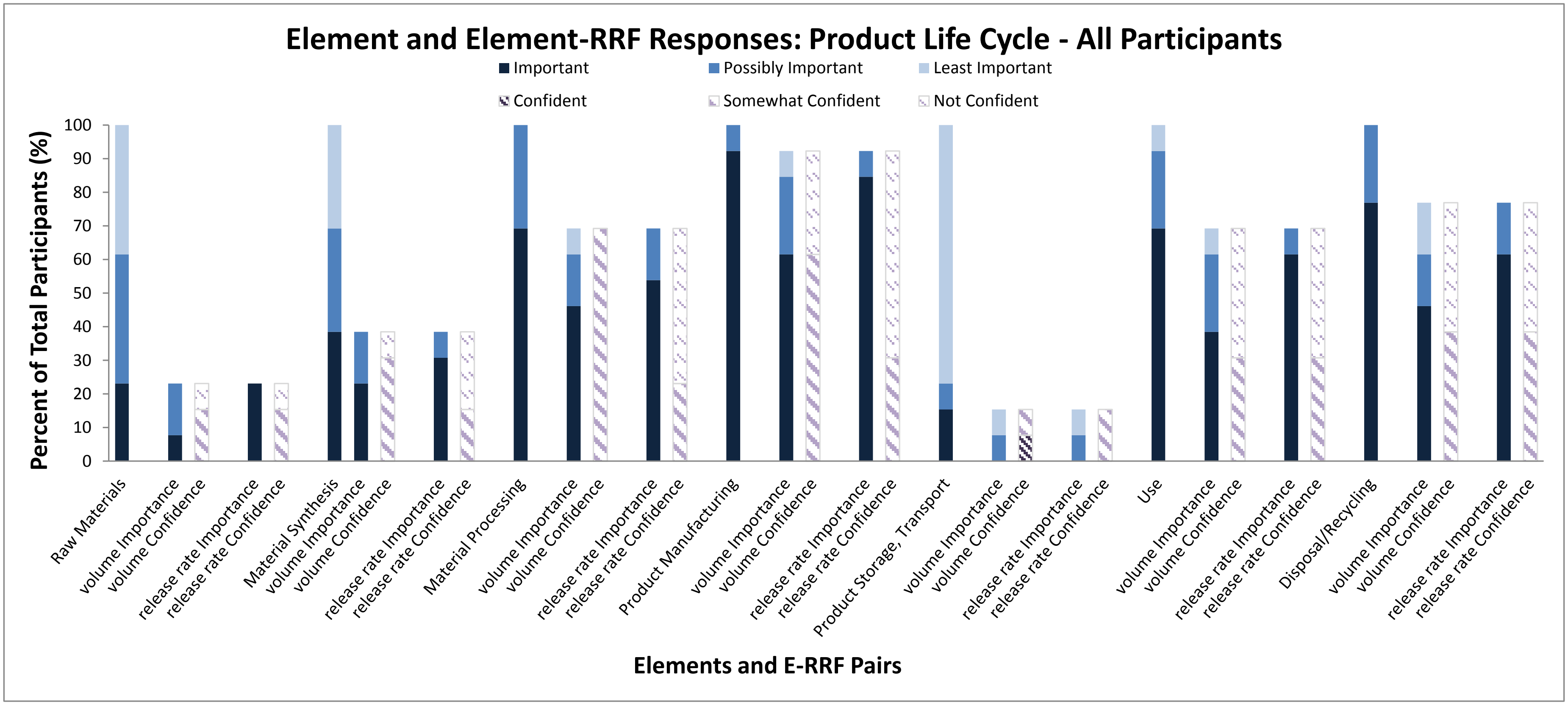
Element Importance Ratings - All Participants
Important
Possibly Important
Least Important
Percent of Total Participants (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Raw Materials
Material Synthesis
Material Processing
Product Manufacturing
Product Storage, Transport
Use
Disposal/Recycling
Air
Surface Water
Groundwater
Wastewater
Sediment
Soil
Biota
Human: Occupational
Human: Consumer
Human: General Population
Aquatic Biota (Exposure Route)
Terrestrial Biota (Exposure Route)
Abiotic (Exposure Route)
Human (Dose (Kinetics))
Aquatic Biota (Dose (Kinetics))
Terrestrial Biota (Dose (Kinetics))
Abiotic (Dose (Kinetics))
Human (Impacts)
Aquatic Biota (Impacts)
Terrestrial Biota (Impacts)
Other
Element

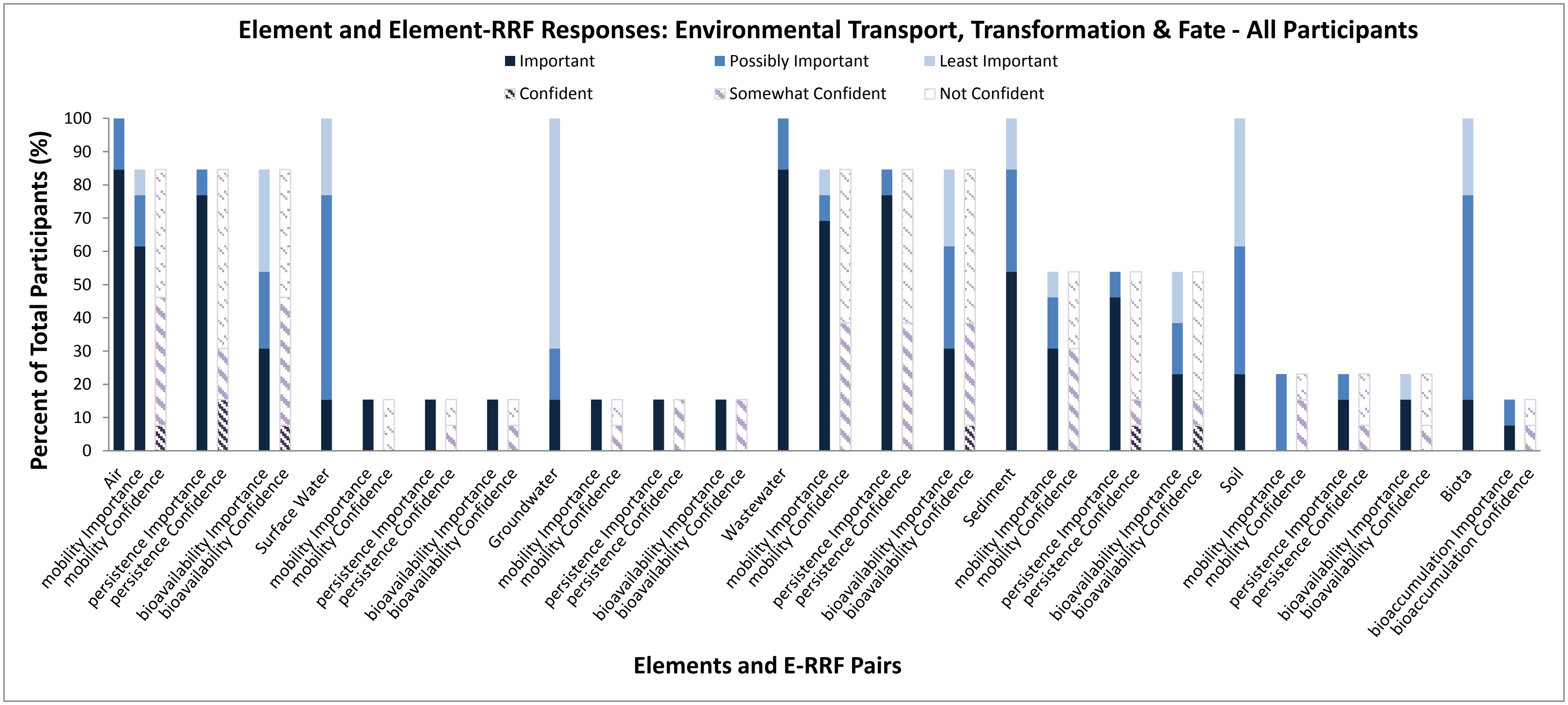
3. Group Results: Importance/Confidence Matrix of Element-Risk Relevance Factor (E-RRF) Pairs

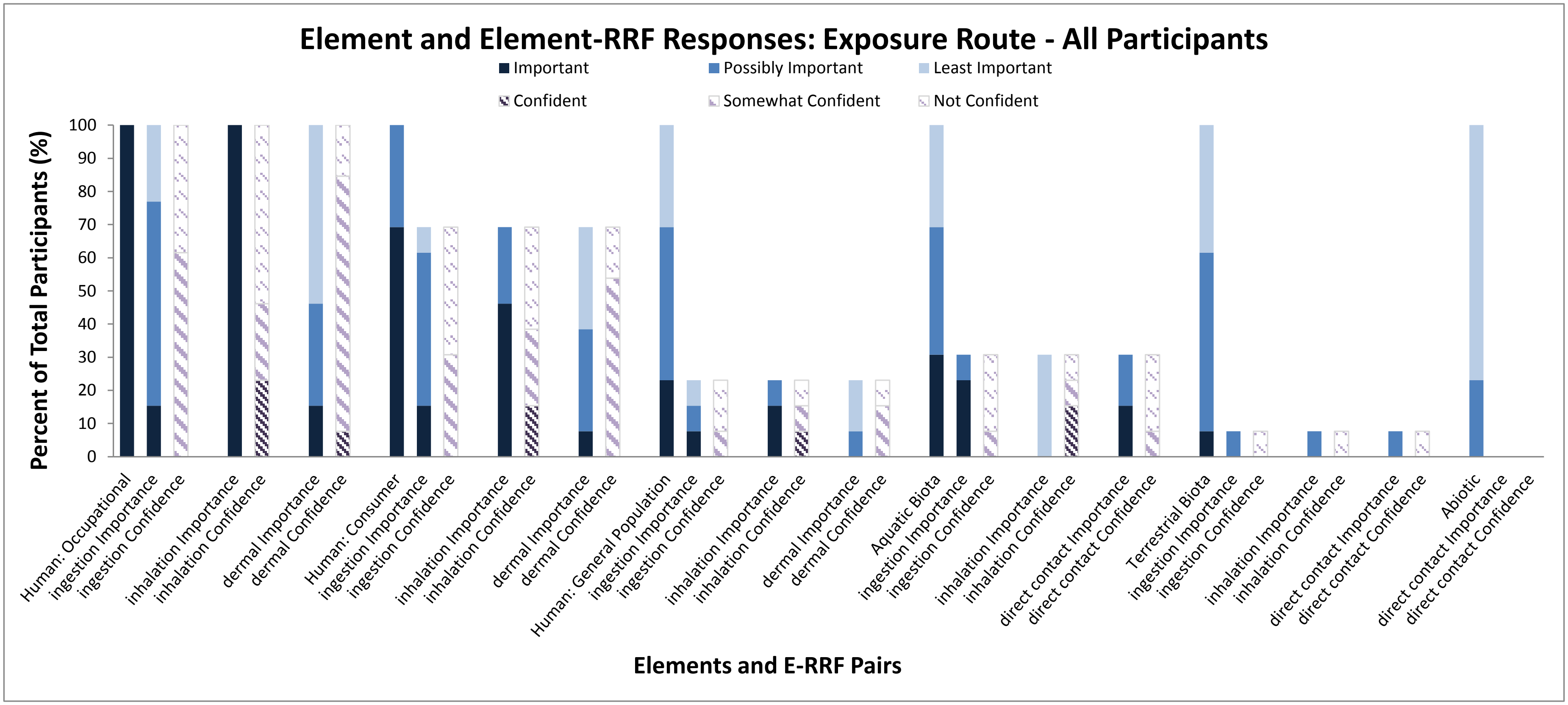
*I: %; C: % represents the percentage of total respondents who chose the cell's Importance and Confidence responses, respectively, for the listed Element-Risk Relevance Factor.

	Confident	Somewhat Confident	Not Confident
Important		• Product Life Cycle-Material Synthesis-Volume, I: 23%; C: 31% • Product Life Cycle-Material Processing-Volume, I: 46%; C: 69% • Product Life Cycle-Product Manufacturing-Volume, I: 62%; C: 62% • Env. TT&F-Sediment-Mobility, I: 31%; C: 31% • Impacts-Human-Cancer, I: 69%; C: 69%	• Product Life Cycle Material Synthesis Release Rate, I: 31%; C: 23% • Product Life Cycle Material Processing Release Rate, I: 54%; C: 46% • Product Life Cycle Product Manufacturing Release Rate, I: 85%; C: 62% • Product Life Cycle Use Volume, I: 38%; C: 38% • Product Life Cycle Use Release Rate, I: 62%; C: 38% • Product Life Cycle Disposal/Recycling Volume, I: 46%; C: 38% • Product Life Cycle Disposal/Recycling Release Rate, I: 62%; C: 38% • Env. TT&F Air Mobility, I: 62%; C: 38% • Env. TT&F Air Persistence, I: 77%; C: 54% • Env. TT&F Air Bioavailability, I: 31%; C: 38% • Env. TT&F Wastewater Mobility, I: 69%; C: 46% • Env. TT&F Wastewater Persistence, I: 77%; C: 46% • Env. TT&F Wastewater Bioavailability, I: 31%; C: 46% • Env. TT&F Sediment Persistence, I: 46%; C: 38% • Env. TT&F Sediment Bioavailability, I: 23%; C: 38% • Exposure Route Human: Occupational Inhalation, I: 100%; C: 54% • Exposure Route Human: Consumer Inhalation, I: 46%; C: 31% • Dose (Kinetics) Human Absorption, I: 62%; C: 46% • Dose (Kinetics) Human Metabolism, I: 46%; C: 46% • Dose (Kinetics) Human Excretion, I: 46%; C: 46% • Impacts Human Non cancer, I: 92%; C: 77% • Impacts Aquatic Biota Developmental, I: 38%; C: 31% • Impacts Aquatic Biota Other Sublethal Endpoints, I: 31%; C: 31% • Impacts Other Economic, I: 15%; C: 23% • Impacts Other Societal, I: 31%; C: 31% • Impacts Other Environmental Resources, I: 23%; C: 23%
Possibly Important		• Exposure Route-Human: Occupational-Ingestion, I: 62%; C: 62% • Exposure Route-Human: Consumer-Dermal, I: 31%; C: 54% • Impacts-Aquatic Biota-Survival, I: 23%; C: 54% • Impacts-Aquatic Biota-Reproductive, I: 38%; C: 31%	• Exposure Route-Human: Consumer-Ingestion, I: 46%; C: 38% • Dose (Kinetics)-Human-Distribution, I: 54%; C: 46% • Impacts-Human-Reproductive/ Developmental, I: 54%; C: 62%
Least Important		• Exposure Route-Human: Occupational-Dermal, I: 54%; C: 77%	

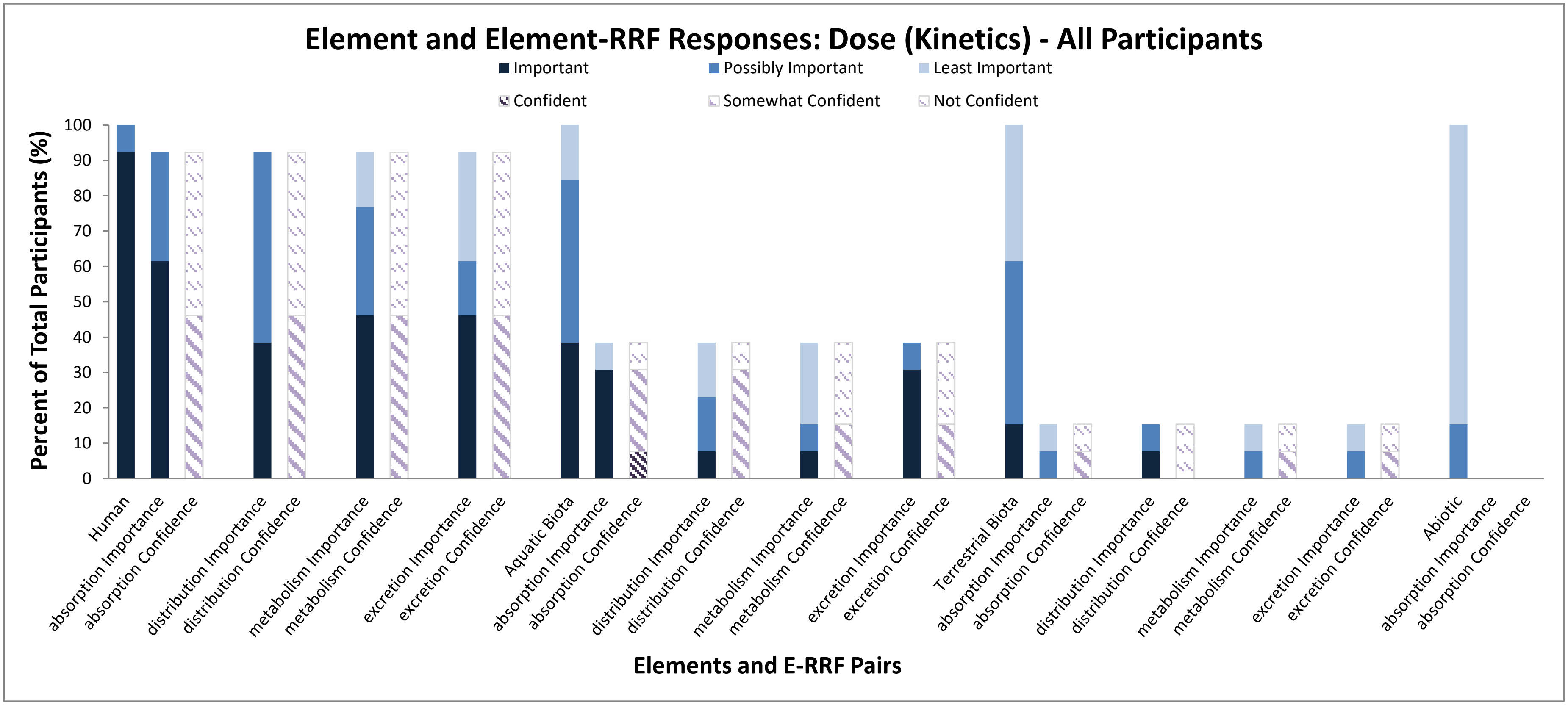
4. Group-Wide CEA Level-Specific Bar Charts

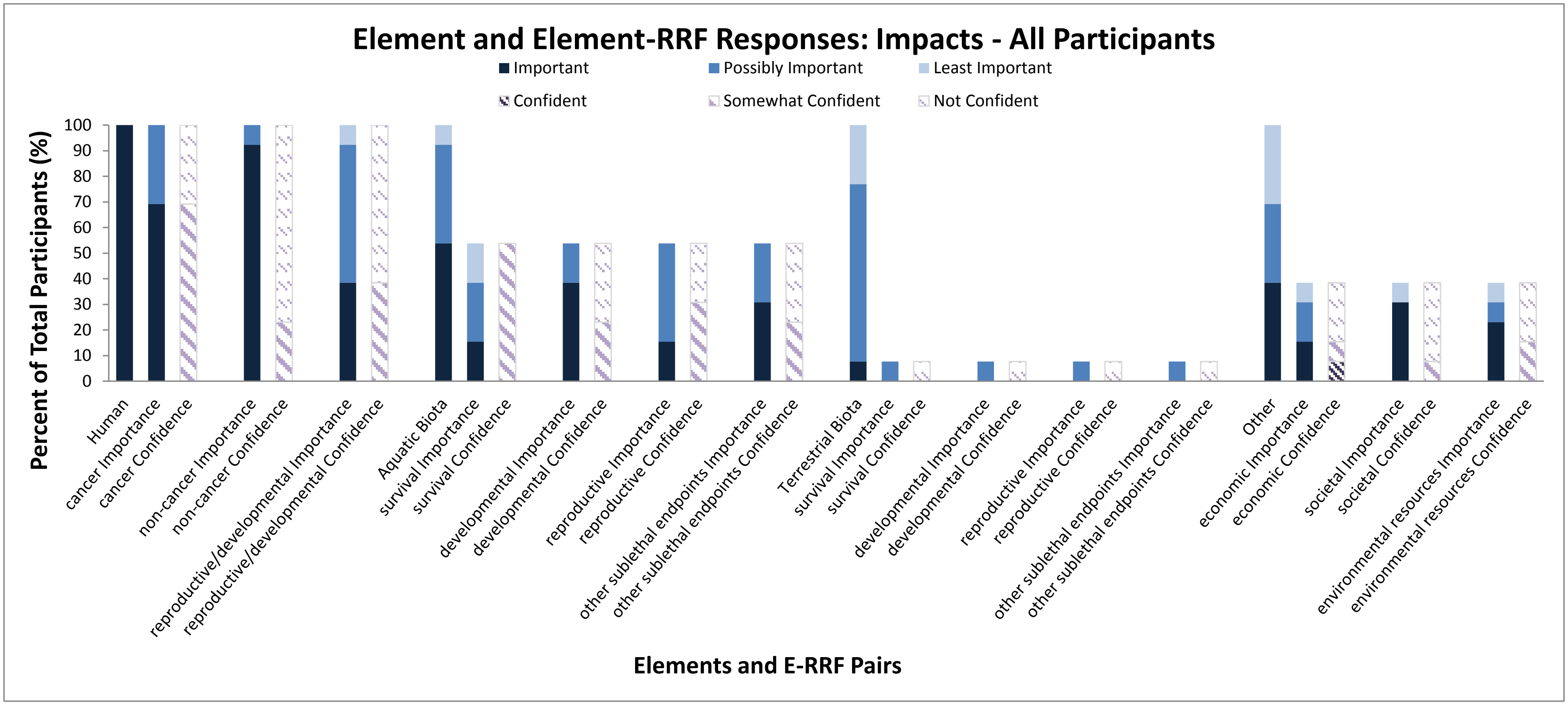

Element and Element-RRF Responses: Product Life Cycle - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Raw Materials
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Synthesis
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Material Processing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Manufacturing
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Product Storage, Transport
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Use
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Disposal/Recycling
volume Importance
volume Confidence
release rate Importance
release rate Confidence
Elements and E-RRF Pairs


Element and Element-RRF Responses: Environmental Transport, Transformation & Fate - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Air
mobility Importance
mobility Confidence
persistence Importance
persistence Confidence
bioavailability Importance
bioavailability Confidence
Surface Water
Groundwater
Wastewater
Sediment
Soil
Biota
bioaccumulation Importance
bioaccumulation Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Exposure Route - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Human: Occupational
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: Consumer
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Human: General Population
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
dermal Importance
dermal Confidence
Aquatic Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Terrestrial Biota
ingestion Importance
ingestion Confidence
inhalation Importance
inhalation Confidence
direct contact Importance
direct contact Confidence
Abiotic
direct contact Importance
direct contact Confidence
Elements and E-RRF Pairs


Element and Element-RRF Responses: Dose (Kinetics) - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
0
10
20
30
40
50
60
70
80
90
100
Human
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Aquatic Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Terrestrial Biota
absorption Importance
absorption Confidence
distribution Importance
distribution Confidence
metabolism Importance
metabolism Confidence
excretion Importance
excretion Confidence
Abiotic
absorption Importance
absorption Confidence
Elements and E-RRF Pairs



Element and Element-RRF Responses: Impacts - All Participants
Important
Possibly Important
Least Important
Confident
Somewhat Confident
Not Confident
Percent of Total Participants (%)
100
90
80
70
60
50
40
30
20
10
0
Human
cancer Importance
cancer Confidence
non-cancer Importance
non-cancer Confidence
reproductive/developmental Importance
reproductive/developmental Confidence
Aquatic Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Terrestrial Biota
survival Importance
survival Confidence
developmental Importance
developmental Confidence
reproductive Importance
reproductive Confidence
other sublethal endpoints Importance
other sublethal endpoints Confidence
Other
economic Importance
economic Confidence
societal Importance
societal Confidence
environmental resources Importance
environmental resources Confidence
Elements and E-RRF Pairs

5. Group Results: Table (with Influential Factors)

Please refer to **Figure 8** in the Summary Report for an overview and explanation of the color-coding of the rows in this table. For example, red rows indicate that the row's Element-Risk Relevance Factor (E-RRF) pair is grouped in the "Important" and "Not Confident" bin of the Importance/Confidence Matrix of E-RRF pairs.

* Represents the number and percentage of participants who ranked the row's Element-Risk Relevance Factor (E-RRF) Pair with the corresponding column's selection.

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
1	Raw Materials-Volume	3(#); 23(%)*	5(#); 38(%)	5(#); 38(%)	1(#); 8(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	1(#); 8(%)	• important to know starting amount of material that is available for potential release	• Analytical Techniques 2(#); 15(%) • Control Technologies 2(#); 15(%) • MWCNT Processing Methods 2(#); 15(%) • MWCNT Purity 2(#); 15(%) • MWCNT Synthesis Methods 2(#); 15(%) • Personal Protective Equipment 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 2(#); 15(%) • Charge 2(#); 15(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 2(#); 15(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 2(#); 15(%) • Exposure Route 2(#); 15(%) • Geographic Location (i.e. rural vs. urban) 2(#); 15(%) • Habitat Structure 2(#); 15(%) • Human Activity 2(#); 15(%) • Individual Activity Level 1(#); 8(%) • Life Stage 2(#); 15(%) • Occupation 2(#); 15(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
2	Raw Materials-Release Rate	3(#); 23(%)	5(#); 38(%)	5(#); 38(%)	3(#); 23(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	1(#); 8(%)	• large volumes of products synthesized can result in large releases	• Analytical Techniques 3(#); 23(%) • Control Technologies 2(#); 15(%) • MWCNT Processing Methods 3(#); 23(%) • MWCNT Purity 3(#); 23(%) • MWCNT Synthesis Methods 3(#); 23(%) • Personal Protective Equipment 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 23(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 3(#); 23(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 2(#); 15(%) • Charge 3(#); 23(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 3(#); 23(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 15(%) • Persistence 3(#); 23(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 3(#); 23(%) • Specific Surface Area 3(#); 23(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 3(#); 23(%) • Water Solubility/Dispersibility 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 15(%) • Groundwater 0(#); 0(%) • Sediment 2(#); 15(%) • Soil 2(#); 15(%) • Surface Water 1(#); 8(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 2(#); 15(%) • Temperature 0(#); 0(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 2(#); 15(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 1(#); 8(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 2(#); 15(%) • Natural Organic Matter (NOM) 2(#); 15(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 2(#); 15(%) • Exposure Route 2(#); 15(%) • Geographic Location (i.e. rural vs. urban) 2(#); 15(%) • Habitat Structure 2(#); 15(%) • Human Activity 2(#); 15(%) • Individual Activity Level 1(#); 8(%) • Life Stage 2(#); 15(%) • Occupation 2(#); 15(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
3	Material Synthesis-Volume	5(#); 38(%)	4(#); 31(%)	4(#); 31(%)	3(#); 23(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	4(#); 31(%)	1(#); 8(%)	• Report is voluntary at this point	• Analytical Techniques 2(#); 15(%) • Control Technologies 3(#); 23(%) • MWCNT Processing Methods 2(#); 15(%) • MWCNT Purity 2(#); 15(%) • MWCNT Synthesis Methods 3(#); 23(%) • Personal Protective Equipment 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 2(#); 15(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 2(#); 15(%) • Charge 2(#); 15(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 2(#); 15(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 15(%) • Persistence 2(#); 15(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 2(#); 15(%) • Exposure Route 2(#); 15(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 1(#); 8(%) • Occupation 2(#); 15(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
4	Materia Synthesis Release Rate	5(#) 38(%)	4(#) 31(%)	4(#) 31(%)	4(#) 31(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	2(#) 15(%)	3(#) 23(%)	• No universal report mechanism is available	• Ana yt ca Techniques 3(#) 23(%) • Contro Techno og es 4(#) 31(%) • MWCNT Process ng Methods 4(#) 31(%) • MWCNT Pur ty 4(#) 31(%) • MWCNT Synthes s Methods 5(#) 38(%) • Persona Protect ve Equipment 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 4(#) 31(%) • Aggregat on/Agg omerat on State 5(#) 38(%) • App ed Coat ngs 4(#) 31(%) • Biodegradability 3(#) 23(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 3(#) 23(%) • Crysta ne Phase 3(#) 23(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 4(#) 31(%) • Morpho ogy (e g aspect rat o ength w dth shape) 4(#); 31(%) • Pers stence 4(#) 31(%) • Redox Potent a 3(#) 23(%) • S ze/S ze D str but on 4(#) 31(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 3 # 23 %) • Surface Chem stry 4(#) 31(%) • Water Solubility/Dispersibility 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 23(%) • Groundwater 1 # 8 %) • Sed ment 2(#) 15(%) • So 2(#) 15(%) • Surface Water 2(#) 15(%) • Wastewater 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 2(#) 15(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 3 # 23 %) • W nd 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 2(#) 15(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 2(#) 15(%) • L gand Concentrat ons n Env ronment 2(#) 15(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 0(#) 0(%) • Surfactant (n Lab) 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 1(#) 8(%) • Microbia Communities in Env ronment 1(#); 8(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 3(#) 23(%) • Chron c Exposure 3(#) 23(%) • Exposure Route 3(#) 23(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 2(#) 15(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 2(#) 15(%) • Occupat on 3(#) 23(%) • Subchronic Exposure 3(#) 23(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
5	Material Processing-Volume	9(#); 69(%)	4(#); 31(%)	0(#); 0(%)	6(#); 46(%)	2(#); 15(%)	1(#); 8(%)	0(#); 0(%)	9(#); 69(%)	0(#); 0(%)	• It depends on the perspective and what information is available, such as confidential information to manufacturers and EPA regulators but little information is available for scientists and the general public • use volumes from DECA BDE for worst case since a mature market • potential for release	• Analytical Techniques 5(#); 38(%) • Control Technologies 4(#); 31(%) • MWCNT Processing Methods 4(#); 31(%) • MWCNT Purity 3(#); 23(%) • MWCNT Synthesis Methods 4(#); 31(%) • Personal Protective Equipment 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 31(%) • Aggregation/Agglomeration State 4(#); 31(%) • Applied Coatings 4(#); 31(%) • Biodegradability 3(#); 23(%) • Catalytic Activity 3(#); 23(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 3(#); 23(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 3(#); 23(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 38(%) • Persistence 4(#); 31(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 5(#); 38(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 4(#); 31(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 31(%) • Groundwater 1(#); 8(%) • Sediment 3(#); 23(%) • Soil 3(#); 23(%) • Surface Water 2(#); 15(%) • Wastewater 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 2(#); 15(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 2(#); 15(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 2(#); 15(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 3(#); 23(%) • Exposure Route 2(#); 15(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 2(#); 15(%) • Occupation 3(#); 23(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
6	Material Processing Release Rate	9(#) 69(%)	4(#) 31(%)	0(#); 0(%)	7(#) 54(%)	2(#) 15(%)	0(#); 0(%)	0(#); 0(%)	3(#) 23(%)	6(#) 46(%)	• Better analytical methods are needed for carbon nanotube quantification • not enough data on releases from processing, envision fabric coating operations resulting in releases to environment, need to understand the form of release (matrix bound, aggregate, etc.) • critical to determine exposure	• Ana yt ca Techniques 7(#) 54(%) • Contro Techno og es 4(#) 31(%) • MWCNT Process ng Methods 4(#) 31(%) • MWCNT Pur ty 3(#) 23(%) • MWCNT Synthes s Methods 4(#) 31(%) • Persona Protect ve Equipment 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 4(#) 31(%) • Aggregat on/Agg omerat on State 5(#) 38(%) • App ed Coat ngs 5(#) 38(%) • Biodegradability 3(#) 23(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 3(#) 23(%) • Crysta ne Phase 2(#) 15(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 5(#) 38(%) • Morpho ogy (e g aspect rat o ength w dth shape) 5(#); 38(%) • Pers stence 4(#) 31(%) • Redox Potent a 2(#) 15(%) • S ze/S ze D str but on 5(#) 38(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 2 # 15 %) • Surface Chem stry 4(#) 31(%) • Water Solubility/Dispersibility 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 4(#) 31(%) • Groundwater 1 # 8 %) • Sed ment 3(#) 23(%) • So 3(#) 23(%) • Surface Water 2(#) 15(%) • Wastewater 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 1(#) 8(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1 # 8 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 2(#) 15(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 2(#) 15(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 3(#) 23(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 1(#) 8(%) • Human Act v ty 1(#) 8(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 2(#) 15(%) • Occupat on 3(#) 23(%) • Subchronic Exposure 2(#) 15(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
7	Product Manufacturing-Volume	12(#); 92(%)	1(#); 8(%)	0(#); 0(%)	8(#); 62(%)	3(#); 23(%)	1(#); 8(%)	0(#); 0(%)	8(#); 62(%)	4(#); 31(%)	• potential for release • It depends on the perspective and what information is available such as confidential information to manufacturers and EPA regulators but little information is available for scientists and the general public • No universal report mechanism is available • assume deca product volumes for worst case scenario	• Analytical Techniques 5(#); 38(%) • Control Technologies 4(#); 31(%) • MWCNT Processing Methods 4(#); 31(%) • MWCNT Purity 4(#); 31(%) • MWCNT Synthesis Methods 5(#); 38(%) • Personal Protective Equipment 7(#); 54(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 23(%) • Aggregation/Agglomeration State 6(#); 46(%) • Applied Coatings 5(#); 38(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 2(#); 15(%) • Charge 3(#); 23(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 1(#); 8(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 4(#); 31(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 31(%) • Persistence 5(#); 38(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 6(#); 46(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 3(#); 23(%) • Surface Chemistry 5(#); 38(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 31(%) • Groundwater 1(#); 8(%) • Sediment 3(#); 23(%) • Soil 2(#); 15(%) • Surface Water 1(#); 8(%) • Wastewater 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 2(#); 15(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 38(%) • Chronic Exposure 5(#); 38(%) • Exposure Route 5(#); 38(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 1(#); 8(%) • Occupation 4(#); 31(%) • Subchronic Exposure 3(#); 23(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
8	Product Manufactur ng Release Rate	12(#) 92(%)	1(#); 8(%)	0(#); 0(%)	11(#) 85(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	4(#) 31(%)	8(#) 62(%)	• Better analytical methods are needed for carbon nanotube quantification • critical to determine exposure • Not enough study	• Ana yt ca Techniques 7(#) 54(%) • Contro Techno og es 5(#) 38(%) • MWCNT Process ng Methods 5(#) 38(%) • MWCNT Pur ty 4(#) 31(%) • MWCNT Synthes s Methods 6(#) 46(%) • Persona Protect ve Equipment 8(#) 62(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 5(#) 38(%) • Aggregat on/Agg omerat on State 8(#) 62(%) • App ed Coat ngs 7(#) 54(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 4(#) 31(%) • Charge 5(#) 38(%) • Conduct ve or Magnet c Propert es 2(#) 15(%) • Crysta ne Phase 2(#) 15(%) • Lipophilicity 4(#) 31(%) • Matr x Bound vs Free 7(#) 54(%) • Morpho ogy (e g aspect rat o ength w dth shape) 7(#); 54(%) • Pers stence 7(#) 54(%) • Redox Potent a 3(#) 23(%) • S ze/S ze D str but on 9(#) 69(%) • Spec f c Surface Area 6(#) 46(%) • Structura Formu a/Mo ecu ar Structure 4 # 31 %) • Surface Chem stry 8(#) 62(%) • Water Solubility/Dispersibility 8(#) 62(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 54(%) • Groundwater 2 # 15 %) • Sed ment 4(#) 31(%) • So 4(#) 31(%) • Surface Water 3(#) 23(%) • Wastewater 6(#) 46(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 1(#) 8(%) • Light Availability 1(#) 8(%) • So Poros ty 1(#) 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 1 # 8 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 3(#) 23(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 4(#) 31(%) • L gand Concentrat ons n Env ronment 2(#) 15(%) • Natural Organ c Matter (NOM) 3(#) 23(%) • Other Contam nants n Env ronment 2(#) 15(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 2(#) 15(%) • Sa n ty 3(#) 23(%) • Surfactant (n Lab) 2(#) 15(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 15(%) • B oaccumu at on 3(#) 23(%) • Biomagnification 1(#) 8(%) • Microbia Communities in Env ronment 2(#) 15(%) • Organ sm Hea th 3(#) 23(%) • Spec es/ ndiv dua Developmenta Behav or 2(#) 15(%) • Spec es/ ndiv dua Feeding Behav or 2(#) 15(%) • Spec es/ ndiv dua Reproduct ve Behav or 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 38(%) • Chron c Exposure 7(#) 54(%) • Exposure Route 6(#) 46(%) • Geograph c Locat on (e rura vs urban) 2(#); 15(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 2(#) 15(%) • ndividua Activity Leve 2(#) 15(%) • L fe Stage 3(#) 23(%) • Occupat on 6(#) 46(%) • Subchronic Exposure 4(#) 31(%) • Suscept b e Populat ons/ ndiv dua s 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
9	Product Storage, Transport-Volume	2(#); 15(%)	1(#); 8(%)	10(#); 77(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	• By the time materials are used for the production of products, manufacturers will be more aware of volume/quantity	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
10	Product Storage, Transport-Release Rate	2(#); 15(%)	1(#); 8(%)	10(#); 77(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	2(#); 15(%)	0(#); 0(%)	• Estimation of Release Rate of particular products could be easily tailored than the materials in previous stages although we dont have any reliable reporting system in this regard	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
11	Use Vo ume	9(#) 69(%)	3(#) 23(%)	1(#); 8(%)	5(#) 38(%)	3(#) 23(%)	1(#); 8(%)	0(#); 0(%)	4(#) 31(%)	5(#) 38(%)	• It depends on the perspective and what information is available such as confidential information to manufacturers and EPA regulators but little information is available for scientists and the general public • use volumes from DECA BDE for worst case scenario since it is a mature market • We don t have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps	• Ana yt ca Techniques 3(#) 23(%) • Contro Techno og es 0(#) 0(%) • MWCNT Process ng Methods 3(#) 23(%) • MWCNT Pur ty 3(#) 23(%) • MWCNT Synthes s Methods 1(#); 8(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 3(#) 23(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 4(#) 31(%) • Biodegradability 2(#) 15(%) • Cata ytic Activ ty 2(#) 15(%) • Charge 3(#) 23(%) • Conduct ve or Magnet c Propert es 1(#); 8(%) • Crysta ne Phase 1(#) 8(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 5(#) 38(%) • Morpho ogy (e g aspect rat o ength w dth shape) 5(#); 38(%) • Pers stence 3(#) 23(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 5(#) 38(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 1 # 8 %) • Surface Chem stry 4(#) 31(%) • Water Solubility/Dispersibility 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 15(%) • Groundwater 0 # 0 %) • Sed ment 1(#) 8(%) • So 1(#) 8(%) • Surface Water 0(#) 0(%) • Wastewater 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 1(#) 8(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 1(#) 8(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 1(#); 8(%) • Other Contam nants n Env ronment 2(#) 15(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 4(#) 31(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 2(#); 15(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 3(#) 23(%) • ndividua Activity Leve 2(#) 15(%) • L fe Stage 4(#) 31(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 4(#) 31(%) • Suscept b e Populat ons/ ndiv dua s 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
12	Use-Release Rate	9(#) 69(%)	3(#) 23(%)	1(#); 8(%)	8(#) 62(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	4(#) 31(%)	5(#) 38(%)	• Better analytical methods are needed for carbon nanotube quantification • this is most important parameter for consumer exposure but how do we realistically test the release from furniture since we are looking at long term • We don t have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps	• Ana yt ca Techniques 4(#) 31(%) • Contro Techno og es 0(#) 0(%) • MWCNT Process ng Methods 3(#) 23(%) • MWCNT Pur ty 3(#) 23(%) • MWCNT Synthes s Methods 1(#); 8(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 3(#) 23(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 5(#) 38(%) • Biodegradability 2(#) 15(%) • Cata ytic Activ ty 2(#) 15(%) • Charge 3(#) 23(%) • Conduct ve or Magnet c Propert es 1(#); 8(%) • Crysta ne Phase 1(#) 8(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 6(#) 46(%) • Morpho ogy (e g aspect rat o ength w dth shape) 6(#); 46(%) • Pers stence 3(#) 23(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 6(#) 46(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 1 # 8 %) • Surface Chem stry 4(#) 31(%) • Water Solubility/Dispersibility 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 23(%) • Groundwater 0 # 0 %) • Sed ment 1(#) 8(%) • So 2(#) 15(%) • Surface Water 1(#) 8(%) • Wastewater 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1 # 8 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 2(#) 15(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 1(#) 8(%) • onic Strength n Env ronment 2(#) 15(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 2(#) 15(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 2(#) 15(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 4(#) 31(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 2(#); 15(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 3(#) 23(%) • ndividua Activity Leve 2(#) 15(%) • L fe Stage 4(#) 31(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 4(#) 31(%) • Suscept b e Populat ons/ ndiv dua s 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
13	Disposal/Recycling Vo ume	10(#) 77(%)	3(#) 23(%)	0(#); 0(%)	6(#) 46(%)	2(#) 15(%)	2(#) 15(%)	0(#); 0(%)	5(#) 38(%)	5(#) 38(%)	• potential for release • estimate based on Deca data • It is unclear to what extent products will be recycled. This information is not available yet and may not be until the products are on the market • We don t have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps	• Ana yt ca Techniques 4(#) 31(%) • Contro Techno og es 1(#) 8(%) • MWCNT Process ng Methods 1(#); 8(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 1(#); 8(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 2(#) 15(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 3(#) 23(%) • Biodegradability 1(#) 8(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 1(#); 8(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 0(#) 0(%) • Matr x Bound vs Free 1(#) 8(%) • Morpho ogy (e g aspect rat o ength w dth shape) 1(#); 8(%) • Pers stence 4(#) 31(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 3(#) 23(%) • Spec f c Surface Area 3(#) 23(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 3(#) 23(%) • Water Solubility/Dispersibility 3(#) 23(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 23(%) • Groundwater 1 # 8 %) • Sed ment 2(#) 15(%) • So 1(#) 8(%) • Surface Water 2(#) 15(%) • Wastewater 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 0(#); 0(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 1(#) 8(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 1(#); 8(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 1(#); 8(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 1(#) 8(%) • Spec es/ ndiv dua Feeding Behav or 1(#); 8(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 3(#) 23(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 0(#) 0(%) • Suscept b e Populat ons/ ndiv dua s 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
14	Disposal/Recycling Release Rate	10(#) 77(%)	3(#) 23(%)	0(#); 0(%)	8(#) 62(%)	2(#) 15(%)	0(#); 0(%)	0(#); 0(%)	5(#) 38(%)	5(#) 38(%)	• Better analytical methods are needed for carbon nanotube quantification. It also depends upon how the recycling is performed. • critical to determine exposure • if waste is incinerated releases to air, if landfilled releases to water possible • Large volumes of waste may be accumulated and increase the potential for a release event • unsure what innovative recycling methods may evolve or what secondary products emerge • We don t have a system like a national registry. However, this step will be less critical for exposure/risk assessment than previous steps.	• Ana yt ca Techniques 4(#) 31(%) • Contro Techno og es 1(#) 8(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 3(#) 23(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 3(#) 23(%) • Biodegradability 1(#) 8(%) • Cata ytic Activ ty 1(#) 8(%) • Charge 2(#) 15(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 1(#) 8(%) • Matr x Bound vs Free 3(#) 23(%) • Morpho ogy (e g aspect rat o ength w dth shape) 3(#); 23(%) • Pers stence 3(#) 23(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 4(#) 31(%) • Spec f c Surface Area 3(#) 23(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 4(#) 31(%) • Water Solubility/Dispersibility 3(#) 23(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 23(%) • Groundwater 0 # 0 %) • Sed ment 2(#) 15(%) • So 1(#) 8(%) • Surface Water 2(#) 15(%) • Wastewater 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1 # 8 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 1(#) 8(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 1(#) 8(%) • onic Strength n Env ronment 2(#) 15(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 2(#) 15(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 1(#); 8(%) • Organ sm Hea th 2(#) 15(%) • Spec es/ ndiv dua Developmenta Behav or 1(#) 8(%) • Spec es/ ndiv dua Feeding Behav or 1(#); 8(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 1(#) 8(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
15	Air Mobility	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	8(#) 62(%)	2(#) 15(%)	1(#); 8(%)	1(#); 8(%)	5(#) 38(%)	5(#) 38(%)	• Insufficient data is available in this regard. • primary route of exposure	• Ana yt ca Techniques 5(#) 38(%) • Contro Techno og es 5(#) 38(%) • MWCNT Process ng Methods 3(#) 23(%) • MWCNT Pur ty 4(#) 31(%) • MWCNT Synthes s Methods 2(#) 15(%) • Persona Protect ve Equipment 3(#) 23(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 4(#) 31(%) • Aggregat on/Agg omerat on State 5(#) 38(%) • App ed Coat ngs 4(#) 31(%) • Biodegradability 3(#) 23(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 2(#) 15(%) • Crysta ne Phase 2(#) 15(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 3(#) 23(%) • Morpho ogy (e g aspect rat o ength w dth shape) 3(#); 23(%) • Pers stence 6(#) 46(%) • Redox Potent a 2(#) 15(%) • S ze/S ze D str but on 5(#) 38(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 3 # 23 %) • Surface Chem stry 5(#) 38(%) • Water Solubility/Dispersibility 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 6(#) 46(%) • Groundwater 0 # 0 %) • Sed ment 1(#) 8(%) • So 1(#) 8(%) • Surface Water 1(#) 8(%) • Wastewater 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 4(#) 31(%) • Light Availability 2(#) 15(%) • So Poros ty 1(#) 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 3 # 23 %) • W nd 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 3(#) 23(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 2(#) 15(%) • Heavy Meta s n Env ronment 1(#) 8(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 1(#); 8(%) • Other Contam nants n Env ronment 2(#) 15(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 15(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 2(#) 15(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 2(#) 15(%) • Spec es/ ndiv dua Developmenta Behav or 1(#) 8(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 3(#) 23(%) • Exposure Route 3(#) 23(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 2(#) 15(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 1(#) 8(%) • Occupat on 2(#) 15(%) • Subchronic Exposure 2(#) 15(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
16	A r Pers stence	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	10(#) 77(%)	1(#); 8(%)	0(#); 0(%)	2(#) 15(%)	2(#) 15(%)	7(#) 54(%)	• known to persist • I am not aware of studies on degradation of carbon nanotubes in air. • Insufficient data is available in this regard. • need to know how long it may remain in the air and be avaiable for inhalation by workers	• Ana yt ca Techniques 5(#) 38(%) • Contro Techno og es 3(#) 23(%) • MWCNT Process ng Methods 2(#) 15(%) • MWCNT Pur ty 3(#) 23(%) • MWCNT Synthes s Methods 1(#); 8(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 3(#) 23(%) • Aggregat on/Agg omerat on State 6(#) 46(%) • App ed Coat ngs 5(#) 38(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 3(#) 23(%) • Crysta ne Phase 3(#) 23(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 3(#) 23(%) • Morpho ogy (e g aspect rat o ength w dth shape) 3(#); 23(%) • Pers stence 7(#) 54(%) • Redox Potent a 3(#) 23(%) • S ze/S ze D str but on 6(#) 46(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 2 # 15 %) • Surface Chem stry 6(#) 46(%) • Water Solubility/Dispersibility 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 7(#) 54(%) • Groundwater 1 # 8 %) • Sed ment 1(#) 8(%) • So 2(#) 15(%) • Surface Water 3(#) 23(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 4(#) 31(%) • Light Availability 4(#) 31(%) • So Poros ty 1(#) 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 5 # 38 %) • W nd 7(#) 54(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 2(#) 15(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 4(#) 31(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 1(#); 8(%) • Other Contam nants n Env ronment 3(#) 23(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 3(#) 23(%) • Exposure Route 4(#) 31(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 3(#) 23(%) • ndividua Activity Leve 2(#) 15(%) • L fe Stage 2(#) 15(%) • Occupat on 2(#) 15(%) • Subchronic Exposure 2(#) 15(%) • Suscept b e Populat ons/ ndiv dua s 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
17	Air Bioavailability	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	4(#) 31(%)	3(#) 23(%)	4(#) 31(%)	1(#); 8(%)	5(#) 38(%)	5(#) 38(%)	• Insufficient data is available in this regard. • Absorption across epithelial tissues has not been observed in other organisms.	• Ana yt ca Techniques 1(#) 8(%) • Contro Techno og es 0(#) 0(%) • MWCNT Process ng Methods 1(#); 8(%) • MWCNT Pur ty 1(#) 8(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 1(#) 8(%) • Aggregat on/Agg omerat on State 2(#) 15(%) • App ed Coat ngs 2(#) 15(%) • Biodegradability 1(#) 8(%) • Cata ytic Activ ty 1(#) 8(%) • Charge 1(#); 8(%) • Conduct ve or Magnet c Propert es 1(#); 8(%) • Crysta ne Phase 1(#) 8(%) • Lipophilicity 1(#) 8(%) • Matr x Bound vs Free 1(#) 8(%) • Morpho ogy (e g aspect rat o ength w dth shape) 1(#); 8(%) • Pers stence 2(#) 15(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 2(#) 15(%) • Spec f c Surface Area 2(#) 15(%) • Structura Formu a/Mo ecu ar Structure 1 # 8 %) • Surface Chem stry 2(#) 15(%) • Water Solubility/Dispersibility 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 15(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 1(#) 8(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 2(#) 15(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 1(#) 8(%) • D sso ved Oxygen Content 1(#) 8(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 0(#); 0(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 1(#); 8(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 0(#) 0(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 0(#) 0(%) • Chron c Exposure 1(#) 8(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 1(#) 8(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 0(#) 0(%) • Suscept b e Populat ons/ ndiv dua s 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
18	Surface Water-Mobility	2(#); 15(%)	8(#); 62(%)	3(#); 23(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)		• Analytical Techniques 2(#); 15(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 2(#); 15(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 15(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
19	Surface Water-Persistence	2(#); 15(%)	8(#); 62(%)	3(#); 23(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 2(#); 15(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 2(#); 15(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 15(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
20	Surface Water-Bioavailability	2(#); 15(%)	8(#); 62(%)	3(#); 23(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 2(#); 15(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 2(#); 15(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 15(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
21	Groundwater-Mobility	2(#); 15(%)	2(#); 15(%)	9(#); 69(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
22	Groundwater-Persistence	2(#); 15(%)	2(#); 15(%)	9(#); 69(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	0(#); 0(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
23	Groundwater-Bioavailability	2(#); 15(%)	2(#); 15(%)	9(#); 69(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	0(#); 0(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
24	Wastewater Mobility	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	9(#) 69(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	5(#) 38(%)	6(#) 46(%)	• expect releases to wastewater from manufacturing and possible washing of textiles by consumers • The extent to which nanotubes are moved or not by wastewater treatment processes determines which environmental compartment is exposed (water or soil). Also, no studies have been conducted on this topic. • Despite not much studies have been conductedin CNT in wastewater, the physciochemical charateristics of CNTs in water media have been similar to some other ultrafine and nano materials.	• Ana yt ca Techniques 7(#) 54(%) • Contro Techno og es 5(#) 38(%) • MWCNT Process ng Methods 3(#) 23(%) • MWCNT Pur ty 5(#) 38(%) • MWCNT Synthes s Methods 2(#) 15(%) • Persona Protect ve Equipment 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 5(#) 38(%) • Aggregat on/Agg omerat on State 8(#) 62(%) • App ed Coat ngs 6(#) 46(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 2(#) 15(%) • Crysta ne Phase 2(#) 15(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 3(#) 23(%) • Morpho ogy (e g aspect rat o ength w dth shape) 4(#); 31(%) • Pers stence 6(#) 46(%) • Redox Potent a 2(#) 15(%) • S ze/S ze D str but on 6(#) 46(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 3 # 23 %) • Surface Chem stry 7(#) 54(%) • Water Solubility/Dispersibility 7(#) 54(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 1 # 8 %) • Sed ment 3(#) 23(%) • So 2(#) 15(%) • Surface Water 2(#) 15(%) • Wastewater 7(#) 54(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 3(#) 23(%) • Light Availability 0(#) 0(%) • So Poros ty 2(#) 15(%) • Soil/Sediment Fractionation 3(#) 23(%) • Temperature 1 # 8 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 3(#) 23(%) • D spers ng Agents 3(#) 23(%) • D sso ved Oxygen Content 3(#) 23(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 5(#) 38(%) • L gand Concentrat ons n Env ronment 4(#) 31(%) • Natural Organ c Matter (NOM) 5(#) 38(%) • Other Contam nants n Env ronment 4(#) 31(%) • pH 3(#) 23(%) • Prote n Concentrat on n Env ronment 4(#) 31(%) • Sa n ty 5(#) 38(%) • Surfactant (n Lab) 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 15(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 1(#) 8(%) • Microbia Communities in Env ronment 5(#) 38(%) • Organ sm Hea th 1(#) 8(%) • Spec es/ ndiv dua Developmenta Behav or 2(#) 15(%) • Spec es/ ndiv dua Feeding Behav or 2(#) 15(%) • Spec es/ ndiv dua Reproduct ve Behav or 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 1(#) 8(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 1(#) 8(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
25	Wastewater Pers stence	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	10(#) 77(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	5(#) 38(%)	6(#) 46(%)	• UNSURE HOW STRUCTURE CHANGES • It is unlikely that substantial degradation will occur given results in other studies. • MWCNTs appear to be persistant • The CNT has not been observed in wastewater system in U.S. And persistnece aspect of CNT in the water may need to be investigated. However, controlling nano in wastewater system is not to be believeds as challenging as those in the air.	• Ana yt ca Techniques 7(#) 54(%) • Contro Techno og es 5(#) 38(%) • MWCNT Process ng Methods 2(#) 15(%) • MWCNT Pur ty 4(#) 31(%) • MWCNT Synthes s Methods 3(#) 23(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 5(#) 38(%) • Aggregat on/Agg omerat on State 8(#) 62(%) • App ed Coat ngs 6(#) 46(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 2(#) 15(%) • Charge 4(#) 31(%) • Conduct ve or Magnet c Propert es 1(#); 8(%) • Crysta ne Phase 1(#) 8(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 4(#) 31(%) • Morpho ogy (e g aspect rat o ength w dth shape) 4(#); 31(%) • Pers stence 6(#) 46(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 6(#) 46(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 2 # 15 %) • Surface Chem stry 8(#) 62(%) • Water Solubility/Dispersibility 8(#) 62(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#); 8(%) • Groundwater 1 # 8 %) • Sed ment 3(#) 23(%) • So 2(#) 15(%) • Surface Water 1(#) 8(%) • Wastewater 7(#) 54(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 2(#) 15(%) • Light Availability 0(#) 0(%) • So Poros ty 2(#) 15(%) • Soil/Sediment Fractionation 2(#) 15(%) • Temperature 2 # 15 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 2(#) 15(%) • D spers ng Agents 3(#) 23(%) • D sso ved Oxygen Content 3(#) 23(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 4(#) 31(%) • L gand Concentrat ons n Env ronment 3(#) 23(%) • Natural Organ c Matter (NOM) 5(#) 38(%) • Other Contam nants n Env ronment 4(#) 31(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 3(#) 23(%) • Sa n ty 4(#) 31(%) • Surfactant (n Lab) 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 4(#) 31(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 2(#) 15(%) • Spec es/ ndiv dua Feeding Behav or 1(#); 8(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 1(#) 8(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 0(#) 0(%) • Suscept b e Populat ons/ ndiv dua s 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
26	Wastewater Bioavailability	11(#) 85(%)	2(#) 15(%)	0(#); 0(%)	4(#) 31(%)	4(#) 31(%)	3(#) 23(%)	1(#); 8(%)	4(#) 31(%)	6(#) 46(%)	• since persistant need more confidence about bioavailability • loadings will never lead to levels that impact WWTP function • Limited amount of study is available although it is less relevant in F&T perspective. • The MWCNTs are likely to interact with the activated sludge given results from studies with other organisms	• Ana yt ca Techniques 6(#) 46(%) • Contro Techno og es 3(#) 23(%) • MWCNT Process ng Methods 1(#); 8(%) • MWCNT Pur ty 3(#) 23(%) • MWCNT Synthes s Methods 3(#) 23(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 4(#) 31(%) • Aggregat on/Agg omerat on State 6(#) 46(%) • App ed Coat ngs 5(#) 38(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 2(#) 15(%) • Charge 2(#) 15(%) • Conduct ve or Magnet c Propert es 1(#); 8(%) • Crysta ne Phase 1(#) 8(%) • Lipophilicity 1(#) 8(%) • Matr x Bound vs Free 3(#) 23(%) • Morpho ogy (e g aspect rat o ength w dth shape) 4(#); 31(%) • Pers stence 5(#) 38(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 5(#) 38(%) • Spec f c Surface Area 4(#) 31(%) • Structura Formu a/Mo ecu ar Structure 2 # 15 %) • Surface Chem stry 6(#) 46(%) • Water Solubility/Dispersibility 6(#) 46(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 1(#); 8(%) • Groundwater 1 # 8 %) • Sed ment 3(#) 23(%) • So 2(#) 15(%) • Surface Water 1(#) 8(%) • Wastewater 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 2(#) 15(%) • Light Availability 0(#) 0(%) • So Poros ty 2(#) 15(%) • Soil/Sediment Fractionation 2(#) 15(%) • Temperature 2 # 15 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 3(#) 23(%) • D sso ved Oxygen Content 3(#) 23(%) • Exposure to Sun ght 1(#) 8(%) • Heavy Meta s n Env ronment 2(#) 15(%) • onic Strength n Env ronment 2(#) 15(%) • L gand Concentrat ons n Env ronment 2(#) 15(%) • Natural Organ c Matter (NOM) 4(#) 31(%) • Other Contam nants n Env ronment 4(#) 31(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 3(#) 23(%) • Sa n ty 2(#) 15(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 1(#); 8(%) • B oaccumu at on 1(#); 8(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 4(#) 31(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 2(#) 15(%) • Spec es/ ndiv dua Feeding Behav or 1(#); 8(%) • Spec es/ ndiv dua Reproduct ve Behav or 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 2(#) 15(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 1(#) 8(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 0(#) 0(%) • Suscept b e Populat ons/ ndiv dua s 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
27	Sediment-Mobility	7(#); 54(%)	4(#); 31(%)	2(#); 15(%)	4(#); 31(%)	2(#); 15(%)	1(#); 8(%)	0(#); 0(%)	4(#); 31(%)	3(#); 23(%)	• Sediment is the ultimate repository for environmental contaminates; material entering waste water will eventually reside in the sediment • The extent that MWCNTs could be redistributed into the water column during scouring events or bioturbation is unclear • expect it to remain in the sediment	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 2(#); 15(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 2(#); 15(%) • Other Contaminants in Environment 2(#); 15(%) • pH 1(#); 8(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
28	Sediment Persistence	7(#); 54(%)	4(#); 31(%)	2(#); 15(%)	6(#); 46(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	5(#); 38(%)	• is persistence • Degradation is likely to be very slow and has not been observed in some studies on uptake	• Analytical Techniques 3(#); 23(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 3(#); 23(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 3(#); 23(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 3(#); 23(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 2(#); 15(%) • Soil/Sediment Fractionation 2(#); 15(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 2(#); 15(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 3(#); 23(%) • Other Contaminants in Environment 2(#); 15(%) • pH 2(#); 15(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
29	Sediment Bioavailability	7(#); 54(%)	4(#); 31(%)	2(#); 15(%)	3(#); 23(%)	2(#); 15(%)	2(#); 15(%)	1(#); 8(%)	1(#); 8(%)	5(#); 38(%)	• since persistant need more confidence about bioavailability • Uptake has not been observed in multiple studies.	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 2(#); 15(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 3(#); 23(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 2(#); 15(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 2(#); 15(%) • Other Contaminants in Environment 2(#); 15(%) • pH 1(#); 8(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
30	Soil-Mobility	3(#); 23(%)	5(#); 38(%)	5(#); 38(%)	0(#); 0(%)	3(#); 23(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
31	Soil-Persistence	3(#); 23(%)	5(#); 38(%)	5(#); 38(%)	2(#); 15(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	2(#); 15(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
32	Soil-Bioavailability	3(#); 23(%)	5(#); 38(%)	5(#); 38(%)	2(#); 15(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	2(#); 15(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
33	Biota-Bioaccumulation	2(#); 15(%)	8(#); 62(%)	3(#); 23(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	• organim uptake may occur over long periods of time (years), long term bioaccumulation needs to be considered	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
34	Human: Occupational-Ingestion	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	8(#); 62(%)	3(#); 23(%)	0(#); 0(%)	8(#); 62(%)	5(#); 38(%)	• do not see much concern from ingestion of MCs based on data • There will likely be good controls to limit exposure via ingestion. • Exposure amount perspective, the relative amount of CNT intake in the form of ingestion would be much lower than inhalation in Occupational settings and there are some studies presenting our luminal surfaces of GI tracks are resistant to the passage of CNTs.	• Analytical Techniques 2(#); 15(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 15(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
35	Human: Occupational-Inhalation	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	3(#); 23(%)	3(#); 23(%)	7(#); 54(%)	• inhalation may be the first intial exposure occurrences with workers • inhalation must be controled as inhalation exposure can cause effects • Studies have been condcuted in insects an some animals, but the exposure routes and administration techinques have been criticized for valid reasons	• Analytical Techniques 7(#); 54(%) • Control Technologies 7(#); 54(%) • MWCNT Processing Methods 6(#); 46(%) • MWCNT Purity 6(#); 46(%) • MWCNT Synthesis Methods 6(#); 46(%) • Personal Protective Equipment 8(#); 62(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 31(%) • Aggregation/Agglomeration State 9(#); 69(%) • Applied Coatings 7(#); 54(%) • Biodegradability 4(#); 31(%) • Catalytic Activity 4(#); 31(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 3(#); 23(%) • Crystalline Phase 3(#); 23(%) • Lipophilicity 3(#); 23(%) • Matrix Bound vs. Free 5(#); 38(%) • Morphology (e.g. aspect ratio, length, width, shape) 6(#); 46(%) • Persistence 7(#); 54(%) • Redox Potential 3(#); 23(%) • Size/Size Distribution 8(#); 62(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 4(#); 31(%) • Surface Chemistry 6(#); 46(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 7(#); 54(%) • Groundwater 1(#); 8(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 2(#); 15(%) • Light Availability 1(#); 8(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 4(#); 31(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 1(#); 8(%) • Heavy Metals in Environment 2(#); 15(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 2(#); 15(%) • pH 2(#); 15(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 3(#); 23(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 2(#); 15(%) • Species/Individual Developmental Behavior 2(#); 15(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 23(%) • Chronic Exposure 5(#); 38(%) • Exposure Route 4(#); 31(%) • Geographic Location (i.e. rural vs. urban) 2(#); 15(%) • Habitat Structure 1(#); 8(%) • Human Activity 3(#); 23(%) • Individual Activity Level 2(#); 15(%) • Life Stage 2(#); 15(%) • Occupation 4(#); 31(%) • Subchronic Exposure 3(#); 23(%) • Susceptible Populations/Individuals 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
36	Human: Occupational-Dermal	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	4(#); 31(%)	7(#); 54(%)	1(#); 8(%)	10(#); 77(%)	2(#); 15(%)	• In some studies using insects, dermal exposure have shown some systematic effects. However, the other routes of exposure (inhalation and ingestion) have not been compleleted blocked. Physicochemical properties of the CNTs known cause less likely a major issue on dermal exposure. • low dermal absorption expected • There will likely be good controls to limit dermal exposure	• Analytical Techniques 1(#); 8(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 1(#); 8(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 8(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 1(#); 8(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
37	Human: Consumer-Ingestion	9(#); 69(%)	4(#); 31(%)	0(#); 0(%)	2(#); 15(%)	6(#); 46(%)	1(#); 8(%)	0(#); 0(%)	4(#); 31(%)	5(#); 38(%)	• need analytics • do not see much concern from ingestion of MCs based on data	• Analytical Techniques 3(#); 23(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 3(#); 23(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 3(#); 23(%) • Water Solubility/Dispersibility 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 8(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
38	Human: Consumer nhalat on	9(#) 69(%)	4(#) 31(%)	0(#); 0(%)	6(#) 46(%)	3(#) 23(%)	0(#); 0(%)	2(#) 15(%)	3(#) 23(%)	4(#) 31(%)	• depends on release rate, if high enough could be an issue	• Ana yt ca Techniques 3(#) 23(%) • Contro Techno og es 2(#) 15(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 1(#) 8(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 1(#) 8(%) • Aggregat on/Agg omerat on State 3(#) 23(%) • App ed Coat ngs 2(#) 15(%) • Biodegradability 0(#) 0(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 0(#) 0(%) • Matr x Bound vs Free 1(#) 8(%) • Morpho ogy (e g aspect rat o ength w dth shape) 1(#); 8(%) • Pers stence 2(#) 15(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 3(#) 23(%) • Spec f c Surface Area 1(#) 8(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 3(#) 23(%) • Water Solubility/Dispersibility 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 2(#) 15(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 0(#) 0(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 0(#); 0(%) • D spers ng Agents 1(#) 8(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 0(#); 0(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 0(#) 0(%) • Chron c Exposure 1(#) 8(%) • Exposure Route 1(#) 8(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 1(#) 8(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 1(#) 8(%) • Occupat on 0(#); 0(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
39	Human: Consumer-Dermal	9(#); 69(%)	4(#); 31(%)	0(#); 0(%)	1(#); 8(%)	4(#); 31(%)	4(#); 31(%)	0(#); 0(%)	7(#); 54(%)	2(#); 15(%)	• depends on dermal absorption rates	• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
40	Human: General Population-Ingestion	3(#); 23(%)	6(#); 46(%)	4(#); 31(%)	1(#); 8(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	2(#); 15(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
41	Human: General Population-Inhalation	3(#); 23(%)	6(#); 46(%)	4(#); 31(%)	2(#); 15(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 1(#); 8(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
42	Human: General Population-Dermal	3(#); 23(%)	6(#); 46(%)	4(#); 31(%)	0(#); 0(%)	1(#); 8(%)	2(#); 15(%)	0(#); 0(%)	2(#); 15(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
43	Aquatic Biota-Ingestion	4(#); 31(%)	5(#); 38(%)	4(#); 31(%)	3(#); 23(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	3(#); 23(%)	• have emissions and expect to collect in sediment which could affect aquatic species	• Analytical Techniques 3(#); 23(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 31(%) • Aggregation/Agglomeration State 4(#); 31(%) • Applied Coatings 3(#); 23(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 1(#); 8(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 2(#); 15(%) • Persistence 3(#); 23(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 3(#); 23(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 3(#); 23(%) • Soil 0(#); 0(%) • Surface Water 3(#); 23(%) • Wastewater 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 2(#); 15(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 2(#); 15(%) • Dissolved Oxygen Content 2(#); 15(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 3(#); 23(%) • Ligand Concentrations in Environment 3(#); 23(%) • Natural Organic Matter (NOM) 3(#); 23(%) • Other Contaminants in Environment 3(#); 23(%) • pH 3(#); 23(%) • Protein Concentration in Environment 3(#); 23(%) • Salinity 3(#); 23(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 2(#); 15(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 2(#); 15(%) • Species/Individual Developmental Behavior 2(#); 15(%) • Species/Individual Feeding Behavior 2(#); 15(%) • Species/Individual Reproductive Behavior 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 1(#); 8(%) • Occupation 1(#); 8(%) • Subchronic Exposure 1(#); 8(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
44	Aquatic Biota-Inhalation	4(#); 31(%)	5(#); 38(%)	4(#); 31(%)	0(#); 0(%)	0(#); 0(%)	4(#); 31(%)	2(#); 15(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
45	Aquatic Biota-Direct Contact	4(#); 31(%)	5(#); 38(%)	4(#); 31(%)	2(#); 15(%)	2(#); 15(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)	3(#); 23(%)	• have emissions and expect to collect in sediment which could affect aquatic species	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 23(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 2(#); 15(%) • Soil 0(#); 0(%) • Surface Water 2(#); 15(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 2(#); 15(%) • Natural Organic Matter (NOM) 2(#); 15(%) • Other Contaminants in Environment 2(#); 15(%) • pH 2(#); 15(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
46	Terrestrial Biota-Ingestion	1(#); 8(%)	7(#); 54(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
47	Terrestrial Biota-Inhalation	1(#); 8(%)	7(#); 54(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
48	Terrestrial Biota-Direct Contact	1(#); 8(%)	7(#); 54(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
49	Abiotic-Direct Contact	0(#); 0(%)	3(#); 23(%)	10(#); 77(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
50	Human-Absorption	12(#); 92(%)	1(#); 8(%)	0(#); 0(%)	8(#); 62(%)	4(#); 31(%)	0(#); 0(%)	0(#); 0(%)	6(#); 46(%)	6(#); 46(%)	• Insufficent data • except for inhalation route absorption needs to occur to have an effect, if not absorbed orally or dermally, significantly reduce concerns from exposure	• Analytical Techniques 5(#); 38(%) • Control Technologies 4(#); 31(%) • MWCNT Processing Methods 4(#); 31(%) • MWCNT Purity 5(#); 38(%) • MWCNT Synthesis Methods 4(#); 31(%) • Personal Protective Equipment 4(#); 31(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 46(%) • Aggregation/Agglomeration State 6(#); 46(%) • Applied Coatings 5(#); 38(%) • Biodegradability 4(#); 31(%) • Catalytic Activity 3(#); 23(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 3(#); 23(%) • Matrix Bound vs. Free 5(#); 38(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 38(%) • Persistence 5(#); 38(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 6(#); 46(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 6(#); 46(%) • Water Solubility/Dispersibility 6(#); 46(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 5(#); 38(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 2(#); 15(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 3(#); 23(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 2(#); 15(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 2(#); 15(%) • pH 3(#); 23(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 23(%) • Bioaccumulation 4(#); 31(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 38(%) • Chronic Exposure 6(#); 46(%) • Exposure Route 6(#); 46(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 0(#); 0(%) • Human Activity 4(#); 31(%) • Individual Activity Level 3(#); 23(%) • Life Stage 4(#); 31(%) • Occupation 2(#); 15(%) • Subchronic Exposure 4(#); 31(%) • Susceptible Populations/Individuals 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
51	Human-Distribution	12(#); 92(%)	1(#); 8(%)	0(#); 0(%)	5(#); 38(%)	7(#); 54(%)	0(#); 0(%)	0(#); 0(%)	6(#); 46(%)	6(#); 46(%)	• Insufficent data • distribution within tissues and specific organs could be important to determine risk	• Analytical Techniques 5(#); 38(%) • Control Technologies 4(#); 31(%) • MWCNT Processing Methods 4(#); 31(%) • MWCNT Purity 5(#); 38(%) • MWCNT Synthesis Methods 4(#); 31(%) • Personal Protective Equipment 4(#); 31(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 38(%) • Aggregation/Agglomeration State 6(#); 46(%) • Applied Coatings 5(#); 38(%) • Biodegradability 4(#); 31(%) • Catalytic Activity 3(#); 23(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 3(#); 23(%) • Matrix Bound vs. Free 5(#); 38(%) • Morphology (e.g. aspect ratio, length, width, shape) 5(#); 38(%) • Persistence 5(#); 38(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 6(#); 46(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 5(#); 38(%) • Water Solubility/Dispersibility 6(#); 46(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 31(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 3(#); 23(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 2(#); 15(%) • pH 3(#); 23(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 23(%) • Bioaccumulation 4(#); 31(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 23(%) • Chronic Exposure 4(#); 31(%) • Exposure Route 4(#); 31(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 0(#); 0(%) • Human Activity 2(#); 15(%) • Individual Activity Level 2(#); 15(%) • Life Stage 3(#); 23(%) • Occupation 2(#); 15(%) • Subchronic Exposure 3(#); 23(%) • Susceptible Populations/Individuals 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
52	Human-Metabolism	12(#); 92(%)	1(#); 8(%)	0(#); 0(%)	6(#); 46(%)	4(#); 31(%)	2(#); 15(%)	0(#); 0(%)	6(#); 46(%)	6(#); 46(%)	• Insufficent data	• Analytical Techniques 4(#); 31(%) • Control Technologies 3(#); 23(%) • MWCNT Processing Methods 3(#); 23(%) • MWCNT Purity 4(#); 31(%) • MWCNT Synthesis Methods 3(#); 23(%) • Personal Protective Equipment 2(#); 15(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 3(#); 23(%) • Aggregation/Agglomeration State 5(#); 38(%) • Applied Coatings 3(#); 23(%) • Biodegradability 4(#); 31(%) • Catalytic Activity 2(#); 15(%) • Charge 3(#); 23(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 4(#); 31(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 31(%) • Persistence 5(#); 38(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 5(#); 38(%) • Specific Surface Area 4(#); 31(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 5(#); 38(%) • Water Solubility/Dispersibility 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 4(#); 31(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 3(#); 23(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 1(#); 8(%) • pH 3(#); 23(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 2(#); 15(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 3(#); 23(%) • Chronic Exposure 4(#); 31(%) • Exposure Route 5(#); 38(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 0(#); 0(%) • Human Activity 3(#); 23(%) • Individual Activity Level 2(#); 15(%) • Life Stage 4(#); 31(%) • Occupation 2(#); 15(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
53	Human-Excretion	12(#); 92(%)	1(#); 8(%)	0(#); 0(%)	6(#); 46(%)	2(#); 15(%)	4(#); 31(%)	0(#); 0(%)	6(#); 46(%)	6(#); 46(%)	• Insufficent data	• Analytical Techniques 4(#); 31(%) • Control Technologies 3(#); 23(%) • MWCNT Processing Methods 3(#); 23(%) • MWCNT Purity 4(#); 31(%) • MWCNT Synthesis Methods 3(#); 23(%) • Personal Protective Equipment 3(#); 23(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 4(#); 31(%) • Aggregation/Agglomeration State 5(#); 38(%) • Applied Coatings 4(#); 31(%) • Biodegradability 3(#); 23(%) • Catalytic Activity 2(#); 15(%) • Charge 3(#); 23(%) • Conductive or Magnetic Properties 2(#); 15(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 4(#); 31(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 31(%) • Persistence 5(#); 38(%) • Redox Potential 2(#); 15(%) • Size/Size Distribution 5(#); 38(%) • Specific Surface Area 3(#); 23(%) • Structural Formula/Molecular Structure 2(#); 15(%) • Surface Chemistry 4(#); 31(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 23(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 1(#); 8(%) • Wind 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 2(#); 15(%) • Dispersing Agents 3(#); 23(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 2(#); 15(%) • Ligand Concentrations in Environment 2(#); 15(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 2(#); 15(%) • pH 3(#); 23(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 3(#); 23(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 3(#); 23(%) • Exposure Route 3(#); 23(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 0(#); 0(%) • Human Activity 2(#); 15(%) • Individual Activity Level 2(#); 15(%) • Life Stage 3(#); 23(%) • Occupation 2(#); 15(%) • Subchronic Exposure 2(#); 15(%) • Susceptible Populations/Individuals 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
54	Aquatic Biota-Absorption	5(#); 38(%)	6(#); 46(%)	2(#); 15(%)	4(#); 31(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	3(#); 23(%)	1(#); 8(%)	• is it absorbed by aquatic species is key for exposure	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 2(#); 15(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
55	Aquatic Biota-Distribution	5(#); 38(%)	6(#); 46(%)	2(#); 15(%)	1(#); 8(%)	2(#); 15(%)	2(#); 15(%)	0(#); 0(%)	4(#); 31(%)	1(#); 8(%)	• depends on absoption	• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
56	Aquatic Biota-Metabolism	5(#); 38(%)	6(#); 46(%)	2(#); 15(%)	1(#); 8(%)	1(#); 8(%)	3(#); 23(%)	0(#); 0(%)	2(#); 15(%)	3(#); 23(%)	• depends on absoption	• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 0(#); 0(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
57	Aquatic Biota-Excretion	5(#); 38(%)	6(#); 46(%)	2(#); 15(%)	4(#); 31(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)	3(#); 23(%)	• depends on absoption	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 1(#); 8(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 2(#); 15(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 0(#); 0(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 2(#); 15(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
58	Terrestrial Biota-Absorption	2(#); 15(%)	6(#); 46(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
59	Terrestrial Biota-Distribution	2(#); 15(%)	6(#); 46(%)	5(#); 38(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	2(#); 15(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 0(#); 0(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 2(#); 15(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 2(#); 15(%) • Soil 2(#); 15(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 1(#); 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 1(#); 8(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 0(#); 0(%) • pH 1(#); 8(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 2(#); 15(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 2(#); 15(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
60	Terrestrial Biota-Metabolism	2(#); 15(%)	6(#); 46(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 0(#); 0(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
61	Terrestrial Biota-Excretion	2(#); 15(%)	6(#); 46(%)	5(#); 38(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	1(#); 8(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 1(#); 8(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
62	Abiotic-Absorption	0(#); 0(%)	2(#); 15(%)	11(#); 85(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)		• Analytical Techniques 0(#); 0(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 0(#); 0(%) • Aggregation/Agglomeration State 0(#); 0(%) • Applied Coatings 0(#); 0(%) • Biodegradability 0(#); 0(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 0(#); 0(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 0(#); 0(%) • Persistence 0(#); 0(%) • Redox Potential 0(#); 0(%) • Size/Size Distribution 0(#); 0(%) • Specific Surface Area 0(#); 0(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 0(#); 0(%) • Bioaccumulation 0(#); 0(%) • Biomagnification 0(#); 0(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 0(#); 0(%) • Species/Individual Developmental Behavior 0(#); 0(%) • Species/Individual Feeding Behavior 0(#); 0(%) • Species/Individual Reproductive Behavior 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 0(#); 0(%) • Chronic Exposure 0(#); 0(%) • Exposure Route 0(#); 0(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 0(#); 0(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 0(#); 0(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why
		I	PI	LI	I	PI	LI	C	SC	NC	
63	Human-Cancer	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	9(#); 69(%)	4(#); 31(%)	0(#); 0(%)	0(#); 0(%)	9(#); 69(%)	4(#); 31(%)	• Insufficient data
64	Human-Non-cancer	13(#) 100(%)	0(#); 0(%)	0(#); 0(%)	12(#) 92(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	3(#) 23(%)	10(#) 77(%)	• Insufficient data
65	Human-Reproductive/ Developmental	13(#); 100(%)	0(#); 0(%)	0(#); 0(%)	5(#); 38(%)	7(#); 54(%)	1(#); 8(%)	0(#); 0(%)	5(#); 38(%)	8(#); 62(%)	• Insufficient data

ID	Element-RRF Pair	Influential Factors						
		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
63	Human-Cancer	• Analytical Techniques 6(#); 46(%) • Control Technologies 3(#); 23(%) • MWCNT Processing Methods 2(#); 15(%) • MWCNT Purity 3(#); 23(%) • MWCNT Synthesis Methods 4(#); 31(%) • Personal Protective Equipment 3(#); 23(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 6(#); 46(%) • Aggregation/Agglomeration State 7(#); 54(%) • Applied Coatings 6(#); 46(%) • Biodegradability 5(#); 38(%) • Catalytic Activity 4(#); 31(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 3(#); 23(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 3(#); 23(%) • Matrix Bound vs. Free 5(#); 38(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 31(%) • Persistence 7(#); 54(%) • Redox Potential 4(#); 31(%) • Size/Size Distribution 7(#); 54(%) • Specific Surface Area 5(#); 38(%) • Structural Formula/Molecular Structure 3(#); 23(%) • Surface Chemistry 6(#); 46(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 2(#); 15(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 2(#); 15(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 1(#); 8(%) • Heavy Metals in Environment 2(#); 15(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 2(#); 15(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 2(#); 15(%) • pH 2(#); 15(%) • Protein Concentration in Environment 2(#); 15(%) • Salinity 2(#); 15(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 23(%) • Bioaccumulation 3(#); 23(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 2(#); 15(%) • Species/Individual Reproductive Behavior 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 5(#); 38(%) • Chronic Exposure 6(#); 46(%) • Exposure Route 5(#); 38(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 2(#); 15(%) • Individual Activity Level 2(#); 15(%) • Life Stage 3(#); 23(%) • Occupation 4(#); 31(%) • Subchronic Exposure 4(#); 31(%) • Susceptible Populations/Individuals 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
64	Human-Non-cancer	• Ana yt ca Techniques 7(#) 54(%) • Contro Techno og es 3(#) 23(%) • MWCNT Process ng Methods 2(#) 15(%) • MWCNT Pur ty 2(#) 15(%) • MWCNT Synthes s Methods 3(#) 23(%) • Persona Protect ve Equipment 2(#) 15(%) • Other 1(#); 8(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 5(#) 38(%) • Aggregat on/Agg omerat on State 7(#) 54(%) • App ed Coat ngs 5(#) 38(%) • Biodegradability 4(#) 31(%) • Cata ytic Activ ty 3(#) 23(%) • Charge 3(#) 23(%) • Conduct ve or Magnet c Propert es 3(#) 23(%) • Crysta ne Phase 2(#) 15(%) • Lipophilicity 3(#) 23(%) • Matr x Bound vs Free 5(#) 38(%) • Morpho ogy (e g aspect rat o ength w dth shape) 3(#); 23(%) • Pers stence 6(#) 46(%) • Redox Potent a 3(#) 23(%) • S ze/S ze D str but on 7(#) 54(%) • Spec f c Surface Area 5(#) 38(%) • Structura Formu a/Mo ecu ar Structure 2 # 15 %) • Surface Chem stry 6(#) 46(%) • Water Solubility/Dispersibility 5(#) 38(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 3(#) 23(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 0(#) 0(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 1(#); 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 2(#) 15(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 0(#); 0(%) • L gand Concentrat ons n Env ronment 1(#); 8(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 1(#); 8(%) • pH 2(#) 15(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 4(#) 31(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 1(#) 8(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 2(#) 15(%) • Spec es/ ndiv dua Developmenta Behav or 3(#) 23(%) • Spec es/ ndiv dua Feeding Behav or 2(#) 15(%) • Spec es/ ndiv dua Reproduct ve Behav or 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 5(#) 38(%) • Chron c Exposure 6(#) 46(%) • Exposure Route 5(#) 38(%) • Geograph c Locat on (e rura vs urban) 1(#); 8(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 3(#) 23(%) • ndividua Activity Leve 3(#) 23(%) • L fe Stage 3(#) 23(%) • Occupat on 5(#) 38(%) • Subchronic Exposure 2(#) 15(%) • Suscept b e Populat ons/ ndiv dua s 4(#) 31(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
65	Human-Reproductive/ Developmental	• Analytical Techniques 6(#); 46(%) • Control Technologies 4(#); 31(%) • MWCNT Processing Methods 3(#); 23(%) • MWCNT Purity 3(#); 23(%) • MWCNT Synthesis Methods 4(#); 31(%) • Personal Protective Equipment 3(#); 23(%) • Other 1(#); 8(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 5(#); 38(%) • Aggregation/Agglomeration State 6(#); 46(%) • Applied Coatings 5(#); 38(%) • Biodegradability 4(#); 31(%) • Catalytic Activity 4(#); 31(%) • Charge 4(#); 31(%) • Conductive or Magnetic Properties 3(#); 23(%) • Crystalline Phase 2(#); 15(%) • Lipophilicity 3(#); 23(%) • Matrix Bound vs. Free 4(#); 31(%) • Morphology (e.g. aspect ratio, length, width, shape) 4(#); 31(%) • Persistence 6(#); 46(%) • Redox Potential 3(#); 23(%) • Size/Size Distribution 6(#); 46(%) • Specific Surface Area 5(#); 38(%) • Structural Formula/Molecular Structure 3(#); 23(%) • Surface Chemistry 6(#); 46(%) • Water Solubility/Dispersibility 5(#); 38(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 3(#); 23(%) • Groundwater 0(#); 0(%) • Sediment 0(#); 0(%) • Soil 0(#); 0(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 2(#); 15(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 2(#); 15(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 3(#); 23(%) • Bioaccumulation 3(#); 23(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 0(#); 0(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 2(#); 15(%) • Species/Individual Feeding Behavior 2(#); 15(%) • Species/Individual Reproductive Behavior 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 4(#); 31(%) • Chronic Exposure 5(#); 38(%) • Exposure Route 4(#); 31(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 0(#); 0(%) • Human Activity 2(#); 15(%) • Individual Activity Level 2(#); 15(%) • Life Stage 3(#); 23(%) • Occupation 4(#); 31(%) • Subchronic Exposure 3(#); 23(%) • Susceptible Populations/Individuals 4(#); 31(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
66	Aquatic Biota-Survival	7(#); 54(%)	5(#); 38(%)	1(#); 8(%)	2(#); 15(%)	3(#); 23(%)	2(#); 15(%)	0(#); 0(%)	7(#); 54(%)	0(#); 0(%)	• data does not indicate acute toxicity	• Analytical Techniques 2(#); 15(%) • Control Technologies 1(#); 8(%) • MWCNT Processing Methods 1(#); 8(%) • MWCNT Purity 1(#); 8(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 2(#); 15(%) • Applied Coatings 2(#); 15(%) • Biodegradability 2(#); 15(%) • Catalytic Activity 1(#); 8(%) • Charge 1(#); 8(%) • Conductive or Magnetic Properties 1(#); 8(%) • Crystalline Phase 1(#); 8(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 1(#); 8(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 1(#); 8(%) • Surface Chemistry 1(#); 8(%) • Water Solubility/Dispersibility 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 1(#); 8(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 1(#); 8(%) • Dispersing Agents 1(#); 8(%) • Dissolved Oxygen Content 1(#); 8(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 1(#); 8(%) • Ionic Strength in Environment 1(#); 8(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 1(#); 8(%) • pH 1(#); 8(%) • Protein Concentration in Environment 1(#); 8(%) • Salinity 1(#); 8(%) • Surfactant (in Lab) 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 1(#); 8(%) • Habitat Structure 1(#); 8(%) • Human Activity 1(#); 8(%) • Individual Activity Level 1(#); 8(%) • Life Stage 1(#); 8(%) • Occupation 1(#); 8(%) • Subchronic Exposure 1(#); 8(%) • Susceptible Populations/Individuals 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
67	Aquat c B ota-Developmenta	7(#) 54(%)	5(#) 38(%)	1(#); 8(%)	5(#) 38(%)	2(#) 15(%)	0(#); 0(%)	0(#); 0(%)	3(#) 23(%)	4(#) 31(%)	• as seen with EDCs aquatic species are very sensitive and low exposures can lead to developmenta effects	• Ana yt ca Techniques 3(#) 23(%) • Contro Techno og es 0(#) 0(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 2(#) 15(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 2(#) 15(%) • Biodegradability 1(#) 8(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 1(#) 8(%) • Morpho ogy (e g aspect rat o ength w dth shape) 1(#); 8(%) • Pers stence 2(#) 15(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 3(#) 23(%) • Spec f c Surface Area 3(#) 23(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 2(#) 15(%) • Water Solubility/Dispersibility 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 1 # 8 %) • Sed ment 1(#) 8(%) • So 0(#) 0(%) • Surface Water 2(#) 15(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 1(#) 8(%) • Light Availability 1(#) 8(%) • So Poros ty 1(#) 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 1 # 8 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 2(#) 15(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 15(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 2(#) 15(%) • Microbia Communities in Env ronment 3(#) 23(%) • Organ sm Hea th 2(#) 15(%) • Spec es/ ndiv dua Developmenta Behav or 3(#) 23(%) • Spec es/ ndiv dua Feeding Behav or 3(#) 23(%) • Spec es/ ndiv dua Reproduct ve Behav or 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 2(#) 15(%) • Occupat on 0(#); 0(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
68	Aquatic Biota-Reproductive	7(#); 54(%)	5(#); 38(%)	1(#); 8(%)	2(#); 15(%)	5(#); 38(%)	0(#); 0(%)	0(#); 0(%)	4(#); 31(%)	3(#); 23(%)	• as seen with EDCs aquatic species are very sensitive and low exposures can lead to repro effects	• Analytical Techniques 2(#); 15(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 2(#); 15(%) • Aggregation/Agglomeration State 3(#); 23(%) • Applied Coatings 2(#); 15(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 2(#); 15(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 2(#); 15(%) • Specific Surface Area 2(#); 15(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 2(#); 15(%) • Water Solubility/Dispersibility 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 1(#); 8(%) • Sediment 1(#); 8(%) • Soil 0(#); 0(%) • Surface Water 1(#); 8(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 1(#); 8(%) • Natural Organic Matter (NOM) 1(#); 8(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 2(#); 15(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 2(#); 15(%) • Species/Individual Feeding Behavior 2(#); 15(%) • Species/Individual Reproductive Behavior 2(#); 15(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
69	Aquat c B ota-Other Subletha Endpo nts	7(#) 54(%)	5(#) 38(%)	1(#); 8(%)	4(#) 31(%)	3(#) 23(%)	0(#); 0(%)	0(#); 0(%)	3(#) 23(%)	4(#) 31(%)	• again these are the effects not typically studies until environmental problems occur, need to give adequate attention	• Ana yt ca Techniques 3(#) 23(%) • Contro Techno og es 0(#) 0(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 2(#) 15(%) • Aggregat on/Agg omerat on State 4(#) 31(%) • App ed Coat ngs 2(#) 15(%) • Biodegradability 1(#) 8(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 2(#) 15(%) • Matr x Bound vs Free 1(#) 8(%) • Morpho ogy (e g aspect rat o ength w dth shape) 1(#); 8(%) • Pers stence 2(#) 15(%) • Redox Potent a 1(#) 8(%) • S ze/S ze D str but on 3(#) 23(%) • Spec f c Surface Area 3(#) 23(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 3(#) 23(%) • Water Solubility/Dispersibility 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 1 # 8 %) • Sed ment 1(#) 8(%) • So 0(#) 0(%) • Surface Water 2(#) 15(%) • Wastewater 1(#) 8(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 1(#) 8(%) • Light Availability 1(#) 8(%) • So Poros ty 1(#) 8(%) • Soil/Sediment Fractionation 1(#); 8(%) • Temperature 1 # 8 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 1(#); 8(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 1(#); 8(%) • L gand Concentrat ons n Env ronment 2(#) 15(%) • Natural Organ c Matter (NOM) 2(#) 15(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 1(#); 8(%) • Sa n ty 1(#) 8(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 2(#) 15(%) • B oaccumu at on 2(#) 15(%) • Biomagnification 2(#) 15(%) • Microbia Communities in Env ronment 3(#) 23(%) • Organ sm Hea th 2(#) 15(%) • Spec es/ ndiv dua Developmenta Behav or 3(#) 23(%) • Spec es/ ndiv dua Feeding Behav or 3(#) 23(%) • Spec es/ ndiv dua Reproduct ve Behav or 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 2(#) 15(%) • Exposure Route 2(#) 15(%) • Geograph c Locat on (e rura vs urban) 0(#); 0(%) • Hab tat Structure 2(#) 15(%) • Human Act v ty 0(#) 0(%) • ndividua Activity Leve 1(#) 8(%) • L fe Stage 2(#) 15(%) • Occupat on 0(#); 0(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
70	Terrestrial Biota-Survival	1(#); 8(%)	9(#); 69(%)	3(#); 23(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)
71	Terrestrial Biota-Developmental	1(#); 8(%)	9(#); 69(%)	3(#); 23(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors							
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions	
72	Terrestrial Biota-Reproductive	1(#); 8(%)	9(#); 69(%)	3(#); 23(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	
73	Terrestrial Biota-Other Sublethal Endpoints	1(#); 8(%)	9(#); 69(%)	3(#); 23(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	0(#); 0(%)	0(#); 0(%)	1(#); 8(%)		• Analytical Techniques 1(#); 8(%) • Control Technologies 0(#); 0(%) • MWCNT Processing Methods 0(#); 0(%) • MWCNT Purity 0(#); 0(%) • MWCNT Synthesis Methods 0(#); 0(%) • Personal Protective Equipment 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Adsorption/Desorption Ability 1(#); 8(%) • Aggregation/Agglomeration State 1(#); 8(%) • Applied Coatings 1(#); 8(%) • Biodegradability 1(#); 8(%) • Catalytic Activity 0(#); 0(%) • Charge 0(#); 0(%) • Conductive or Magnetic Properties 0(#); 0(%) • Crystalline Phase 0(#); 0(%) • Lipophilicity 1(#); 8(%) • Matrix Bound vs. Free 0(#); 0(%) • Morphology (e.g. aspect ratio, length, width, shape) 1(#); 8(%) • Persistence 1(#); 8(%) • Redox Potential 1(#); 8(%) • Size/Size Distribution 1(#); 8(%) • Specific Surface Area 1(#); 8(%) • Structural Formula/Molecular Structure 0(#); 0(%) • Surface Chemistry 0(#); 0(%) • Water Solubility/Dispersibility 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Air 0(#); 0(%) • Groundwater 0(#); 0(%) • Sediment 1(#); 8(%) • Soil 1(#); 8(%) • Surface Water 0(#); 0(%) • Wastewater 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Flow Regime 0(#); 0(%) • Light Availability 0(#); 0(%) • Soil Porosity 0(#); 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0(#); 0(%) • Wind 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Conductivity 0(#); 0(%) • Dispersing Agents 0(#); 0(%) • Dissolved Oxygen Content 0(#); 0(%) • Exposure to Sunlight 0(#); 0(%) • Heavy Metals in Environment 0(#); 0(%) • Ionic Strength in Environment 0(#); 0(%) • Ligand Concentrations in Environment 0(#); 0(%) • Natural Organic Matter (NOM) 0(#); 0(%) • Other Contaminants in Environment 0(#); 0(%) • pH 0(#); 0(%) • Protein Concentration in Environment 0(#); 0(%) • Salinity 0(#); 0(%) • Surfactant (in Lab) 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• ADME 1(#); 8(%) • Bioaccumulation 1(#); 8(%) • Biomagnification 1(#); 8(%) • Microbial Communities in Environment 1(#); 8(%) • Organism Health 1(#); 8(%) • Species/Individual Developmental Behavior 1(#); 8(%) • Species/Individual Feeding Behavior 1(#); 8(%) • Species/Individual Reproductive Behavior 1(#); 8(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	• Acute Exposure 1(#); 8(%) • Chronic Exposure 1(#); 8(%) • Exposure Route 1(#); 8(%) • Geographic Location (i.e. rural vs. urban) 0(#); 0(%) • Habitat Structure 1(#); 8(%) • Human Activity 0(#); 0(%) • Individual Activity Level 0(#); 0(%) • Life Stage 1(#); 8(%) • Occupation 0(#); 0(%) • Subchronic Exposure 0(#); 0(%) • Susceptible Populations/Individuals 0(#); 0(%) • Other 0(#); 0(%) • Specify other 0(#); 0(%)	
74	Other Econom c	5(#) 38(%)	4(#) 31(%)	4(#) 31(%)	2(#) 15(%)	2(#) 15(%)	1(#); 8(%)	1(#); 8(%)	1(#); 8(%)	3(#) 23(%)		• Ana yt ca Techniques 1(#) 8(%) • Contro Techno og es 1(#) 8(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 0(#) 0(%) • Aggregat on/Agg omerat on State 0(#) 0(%) • App ed Coat ngs 0(#) 0(%) • Biodegradability 0(#) 0(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 0(#) 0(%) • Matr x Bound vs Free 0(#) 0(%) • Morpho ogy (e g aspect rat o ength w dth shape) 0(#); 0(%) • Pers stence 0(#) 0(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 0(#) 0(%) • Spec f c Surface Area 0(#) 0(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 0(#) 0(%) • Water Solubility/Dispersibility 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 0(#) 0(%) • Wastewater 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 0(#); 0(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 0(#); 0(%) • L gand Concentrat ons n Env ronment 0(#); 0(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 0(#) 0(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 0(#) 0(%) • Chron c Exposure 0(#) 0(%) • Exposure Route 0(#) 0(%) • Geograph c Locat on (e rura vs urban) 2(#); 15(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 2(#) 15(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 1(#) 8(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	

ID	Element-RRF Pair	Element Importance			RRF Importance			RRF Confidence			Why	Influential Factors						
		I	PI	LI	I	PI	LI	C	SC	NC		Methods Techniques	ENM Characteristics	Surrounding Media	Physical Conditions	Chemical Conditions	Biological Conditions	Social Conditions
75	Other Soc eta	5(#) 38(%)	4(#) 31(%)	4(#) 31(%)	4(#) 31(%)	0(#); 0(%)	1(#); 8(%)	0(#); 0(%)	1(#); 8(%)	4(#) 31(%)		• Ana yt ca Techniques 1(#) 8(%) • Contro Techno og es 1(#) 8(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 0(#) 0(%) • Aggregat on/Agg omerat on State 0(#) 0(%) • App ed Coat ngs 0(#) 0(%) • Biodegradability 0(#) 0(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 0(#) 0(%) • Matr x Bound vs Free 0(#) 0(%) • Morpho ogy (e g aspect rat o ength w dth shape) 0(#); 0(%) • Pers stence 0(#) 0(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 0(#) 0(%) • Spec f c Surface Area 0(#) 0(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 0(#) 0(%) • Water Solubility/Dispersibility 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 0(#) 0(%) • Wastewater 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 0(#); 0(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 0(#); 0(%) • L gand Concentrat ons n Env ronment 0(#); 0(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 0(#) 0(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 1(#) 8(%) • Exposure Route 0(#) 0(%) • Geograph c Locat on (e rura vs urban) 3(#); 23(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 3(#) 23(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 1(#) 8(%) • Occupat on 2(#) 15(%) • Subchronic Exposure 2(#) 15(%) • Suscept b e Populat ons/ ndiv dua s 3(#) 23(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)
76	Other Env ronmenta Resources	5(#) 38(%)	4(#) 31(%)	4(#) 31(%)	3(#) 23(%)	1(#); 8(%)	1(#); 8(%)	0(#); 0(%)	2(#) 15(%)	3(#) 23(%)		• Ana yt ca Techniques 2(#) 15(%) • Contro Techno og es 1(#) 8(%) • MWCNT Process ng Methods 0(#); 0(%) • MWCNT Pur ty 0(#) 0(%) • MWCNT Synthes s Methods 0(#); 0(%) • Persona Protect ve Equipment 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Adsorpt on/Desorpt on Abi ty 0(#) 0(%) • Aggregat on/Agg omerat on State 0(#) 0(%) • App ed Coat ngs 0(#) 0(%) • Biodegradability 0(#) 0(%) • Cata ytic Activ ty 0(#) 0(%) • Charge 0(#); 0(%) • Conduct ve or Magnet c Propert es 0(#); 0(%) • Crysta ne Phase 0(#) 0(%) • Lipophilicity 0(#) 0(%) • Matr x Bound vs Free 0(#) 0(%) • Morpho ogy (e g aspect rat o ength w dth shape) 0(#); 0(%) • Pers stence 0(#) 0(%) • Redox Potent a 0(#) 0(%) • S ze/S ze D str but on 0(#) 0(%) • Spec f c Surface Area 0(#) 0(%) • Structura Formu a/Mo ecu ar Structure 0 # 0 %) • Surface Chem stry 0(#) 0(%) • Water Solubility/Dispersibility 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• A r 0(#); 0(%) • Groundwater 0 # 0 %) • Sed ment 0(#) 0(%) • So 0(#) 0(%) • Surface Water 0(#) 0(%) • Wastewater 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• F ow Reg me 0(#) 0(%) • Light Availability 0(#) 0(%) • So Poros ty 0(#) 0(%) • Soil/Sediment Fractionation 0(#); 0(%) • Temperature 0 # 0 %) • W nd 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Conduct v ty 0(#); 0(%) • D spers ng Agents 0(#) 0(%) • D sso ved Oxygen Content 0(#) 0(%) • Exposure to Sun ght 0(#) 0(%) • Heavy Meta s n Env ronment 0(#) 0(%) • onic Strength n Env ronment 0(#); 0(%) • L gand Concentrat ons n Env ronment 0(#); 0(%) • Natural Organ c Matter (NOM) 0(#); 0(%) • Other Contam nants n Env ronment 0(#); 0(%) • pH 0(#); 0(%) • Prote n Concentrat on n Env ronment 0(#); 0(%) • Sa n ty 0(#) 0(%) • Surfactant (n Lab) 0(#) 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• ADME 0(#); 0(%) • B oaccumu at on 0(#); 0(%) • Biomagnification 0(#) 0(%) • Microbia Communities in Env ronment 0(#); 0(%) • Organ sm Hea th 0(#) 0(%) • Spec es/ ndiv dua Developmenta Behav or 0(#) 0(%) • Spec es/ ndiv dua Feeding Behav or 0(#); 0(%) • Spec es/ ndiv dua Reproduct ve Behav or 0(#); 0(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)	• Acute Exposure 1(#) 8(%) • Chron c Exposure 1(#) 8(%) • Exposure Route 0(#) 0(%) • Geograph c Locat on (e rura vs urban) 2(#); 15(%) • Hab tat Structure 0(#) 0(%) • Human Act v ty 2(#) 15(%) • ndividua Activity Leve 0(#) 0(%) • L fe Stage 0(#) 0(%) • Occupat on 1(#); 8(%) • Subchronic Exposure 1(#) 8(%) • Suscept b e Populat ons/ ndiv dua s 2(#) 15(%) • Other 0(#); 0(%) • Spec fy other 0(#) 0(%)

Appendix G
Analyses of Changes between Prioritization Rounds

Appendix G
Analyses of Changes between Prioritization Rounds

G.1 Analyses of Changes from Round 1 to Round 2

Section 3.4 and **Section 3.5** present the Element-Risk Relevance Factor (E-RRF) pairs that were grouped into the “Important” and “Not Confident” bin of the Comprehensive Environmental Assessment (CEA) Importance/Confidence Matrix for CEA Prioritization Rounds 1 and 2, respectively. Although other bins are included on the Matrix, an overwhelming majority of the prioritized E-RRF pairs on the Matrix were grouped into the “Important” and “Not Confident” bin in both Round 1 and Round 2 results.

Table G-1 compares the number and percentages of each CEA Level’s E-RRF pairs that were binned as “Important” and “Not Confident” in Rounds 1 and 2 (based on **Table 2** and **Table 4** in **Section 3**). Overall, the Product Life Cycle CEA Level gained the most E-RRF pairs between Round 1 and Round 2 (21% increase), whereas the Environmental Transport, Transformation & Fate CEA Level and Dose (Kinetics) CEA Level each lost one net E-RRF pair (5% and 8% decrease, respectively). Another notable change from Round 1 to Round 2—as evidenced by the “Change” columns in **Table G-1**—is that the percentage of participants rating these E-RRF pairs as “Important” and “Not Confident” decreased overall, which may be an effect of participants reviewing the results from Round 1 and incorporating the opinions of others into their thought processes prior to CEA Prioritization Round 2.

Table G-1. Changes from Round 1 to Round 2 in E-RRF Pairs binned as “Important” and “Not Confident” by CEA Level

CEA Level	Number of E-RRF Pairs	Number of E-RRF Pairs in “Important,” “Not Confident” Bin			Percentage of E-RRF Pairs in “Important,” “Not Confident” Bin		
		Round 1	Round 2	Change	Round 1	Round 2	Change
Product Life Cycle	14	6	9	+3	43%	64%	+21
Environmental Transport, Transformation & Fate	19	13	12	-1	68%	63%	-5
Exposure Route	16	2	2	0	13%	13%	0
Dose (Kinetics)	13	8	7	-1	62%	54%	-8
Impacts	14	5	5	0	36%	36%	0

G.2 Analyses of Changes from Round 2 to Round 3

Section 3.5 and **Section 3.7** present the E-RRF pairs that were grouped into the “Important” and “Not Confident” bin of the CEA Importance/Confidence Matrix for CEA Prioritization Rounds 2 and 3, respectively. Although other bins are included on the Matrix, an overwhelming majority of the prioritized E-RRF pairs on the Matrix were grouped into the “Important” and “Not Confident” bin in both Round 2 and Round 3 results.

Table G-2 compares the number and percentages of each CEA Level's E-RRF pairs that were binned as "Important" and "Not Confident" between Rounds 2 and 3 (based on **Table 4** and **Table 6** in **Section 3**). Overall, the Impacts CEA Level gained the most E-RRF pairs between Round 2 and Round 3 (7% increase), whereas all other CEA Levels either remained the same (number and percentage of E-RRFs in "Important" and "Not Confident" bin) or decreased between Round 2 and Round 3: Product Life Cycle lost two E-RRFs (14% decrease), Environmental Transport, Transformation & Fate CEA Level lost four E-RRFs (21% decrease), Exposure Route was unchanged, and Dose (Kinetics) CEA Level lost four net E-RRF pairs (31% decrease). Hence, the percentage of participants rating prioritized E-RRF pairs as "Important" and "Not Confident" decreased overall—a trend also observed between Round 1 and Round 2—which may have been an effect of participants reviewing the results from Round 2 and incorporating the opinions of others into their thought processes prior to CEA Prioritization Round 3.

Table G-2. Changes from Round 2 to Round 3 in E-RRF Pairs binned as "Important" and "Not Confident" by CEA Level

CEA Level	Number of E-RRF Pairs	Number of E-RRF Pairs in "Important," "Not Confident" Bin			Percent of E-RRF Pairs in "Important," "Not Confident" Bin		
		Round 2	Round 3	Change	Round 2	Round 3	Change
Product Life Cycle	14	9	7	-2	64%	50%	-14
Environmental Transport, Transformation & Fate	19	12	8	-4	63%	42%	-21
Exposure Route	16	2	2	0	13%	13%	0
Dose (Kinetics)	13	7	3	-4	54%	23%	-31
Impacts	14	5	6	+1	36%	43%	+7

Appendix H
Pre-Prioritization Process Charge to Participants

Appendix H
Pre-Prioritization Process Charge to Participants

H.1 Pre-Prioritization Process Charge to Participants

Participants were asked to answer a total of nine "Charge Questions" issued by U.S. Environmental Protection Agency (EPA) as they worked through the Comprehensive Environmental Assessment (CEA) multiwalled carbon nanotubes (MWCNT) Prioritization Process. As shown in **Table H-1**, four of these questions pertained to the draft case study document and five of them pertained to the prioritization workshop process. Only the responses from participants relevant for the prioritization workshop process are included in the table. Participant responses to the draft case study are available in the revised case study document (see finalized U.S. EPA, 2012b, as current document is still under development).

Table H-1. Charge Questions issued by U.S. EPA

Input on Draft Case Study Document
1. Do you know of additional, specific studies on MWCNT that should be included in the case study to help identify data gaps that are important to support future assessment and risk management efforts for MWCNT in flame-retardant textile coatings?
2. Is the science accurately conveyed throughout the document? If not, please list any areas that need improvement and provide specific comments in the text to highlight areas that should be refined.
3. Does the comparison of decabromodiphenyl ether (decaBDE) and MWCNT in the case study document help to identify research gaps to support future assessments and risk management decisions for MWCNT? If not, please briefly explain.
4. Do you have any specific comments on how this document could be improved?
Input on Prioritization Workshop Process
1. For the prioritization process, are there additional Elements or Risk Relevance Factors that would be beneficial to include in the detailed CEA framework for future applications of this approach for other chemicals, materials, or technologies?
2. For the prioritization process, did you find that including MWCNT-specific Influential Factors allowed you to add more detail to explain what could be important to research about the areas of the CEA you prioritized? Do you have specific suggestions about how the Influential Factor portion of the prioritization process could be improved, or about additional types of Influential Factors that would be beneficial to include?
3. Are the data (i.e., bar charts, data tables, and matrices) from each prioritization round clearly conveyed? Were the collated responses from the group helpful in carrying out prioritization a second time? Do you have specific suggestions for improving how prioritization data are reported?
4. Do you have specific comments on how this prioritization process could be improved?
5. What are the top three detailed research questions that you feel should be priorities for funding to enable future assessments of MWCNT flame-retardant coatings applied to upholstery textiles, in support of risk-based decisions?

H.2 Participant Responses to Charge Questions

The list of responses from participants to the previously listed Charge Questions pertains to their input on the prioritization workshop process (for participant responses to their input on the draft case study, see finalized U.S. EPA, 2012b, as current document is still under development). Note that all participant responses to these questions are included as follows, even those that are similar or repeat other participant responses, to also show the frequency of similar responses from participants.

1. For the prioritization process, are there additional Elements or Risk Relevance Factors that would be beneficial to include in the detailed CEA framework for future applications of this approach for other chemicals, materials, or technologies?

Participant responses:

1. I cannot think of any.
2. Methods for sampling and analysis: There is a need to determine whether analytical methods exist to characterize and quantify the chemical/material of interest.
3. For the prioritization process, I think most of the questions were reasonable, as we know today that how chemicals and materials interact with the environment and living organisms is complex and influenced by a great many factors. However, I would definitely add questions about application—is the technology of concern likely to be used in the application that would lead to a risk of release? If people answer "not confident," then that can help serve as guidance on what to refocus the prioritization onto. The refocus could lead to a more realistic risk scenario, or onto other chemicals of concern used with the material in question. Other specific questions I think need to be considered relative to future CEAs include (A) finished product durability and wear and how that affects release of nanoparticles/chemicals, (B) how finished goods react in specific environments (do they degrade faster, which leads to quicker release, or are they inert in that environment and stay preserved?), (C) how the finished good is recycled/destroyed at its end of life event; regrind and recycle of plastics is different in regard to release of chemicals when compared to waste-to-energy incineration/gasification, (D) how existing Occupational Safety and Health Administration (OSHA) rules would mitigate risk of human exposure, and (E) product lifecycle and likely consumer use—how does this affect release?
4. Perhaps include all additional information available from other carbon-based nanoparticles, which would make comparisons and potential application to MWCNTs more meaningful.
5. No, there are not additional Elements or Risk Relevance Factors that need to be added.
6. I feel there could be additional Elements on the raw materials (i.e., MWCNT and decaBDE) prior to them being combined into a joint material (flame-retardant coatings). I think additional information on the raw materials would help increase the probability that the information obtained through the CEA framework could be applied to other types of materials containing either MWCNTs or decaBDE in combination with something else.
7. I don't have any additional elements or risk factors to add.
8. The Elements or Risk Relevance Factors were useful in thinking through the research issues, but in the end, there is so much unknown that they did not provide any refinement or prioritization. I am not sure how they will be used, if at all, in the final CEA process. It was also challenging to use the Excel spreadsheet for so many elements.
9. No.
10. Risk that material will magnify risk of other materials in the environment. For instance, MWCNT may well concentrate polycyclic aromatic hydrocarbons (PAHs), thus increasing the local hazard from PAHs in the vicinity of the MWCNT. If they had some catalytic effect, perhaps the material would lead to new risk of products from a reaction that would not occur in its absence.
11. Response: This is adequate and already expansive enough.
12. I can't think of any.
13. None that I can currently think of; the list and document were very comprehensive and informative.
14. No.

15. As it is, I feel there are way too many. The long list becomes mind-numbing and based on my own reaction, it was very difficult to maintain focus and consistency.
16. I cannot think of any. The list is pretty complete.
17. No.
18. No.
19. Nanomaterial investigations rely heavily on the ability to accurately characterize the initial product as well as what form it may become once it is released. An area of expansion for future nano-related framework generation may be to further investigate the techniques utilized to characterize parent materials and materials in complex media.
20. The unique physicochemical characteristics that only the materials in nano-scale carry bring us serious concerns related to post-exposure environmental and health impacts. The Elements or Risk Relevance Factors used during the first two rounds of review cover extensive levels of toxicological issues, yet the need for including additional factors for universal applications of the current method/approach in the coming years although the need for a customized way of approach is still anticipated. The fate and transport aspect of MWCNTs while they are in the plasma would be one factor to be investigated. This may require understanding on the interaction between MWCNT and endothelium, glomerular filtration process, plasma proteins including albumin, among others.
21. No, the risk space is well addressed.
22. None.
23. I think it would actually be beneficial to remove some RRF factors that don't make sense as I understood them, such as inhalation for aquatic biota. Given that MWCNTs are not volatile, it is unclear to me how much the inhalation route would make sense for terrestrial biota either, although there could conceivably be some effect if there were huge airborne concentrations of MWCNTs. What also would have been helpful with the ranking was more clarification about what specific factors should be considered when making the choices for the "exposure route," "dose (kinetics)," and "impacts," since those topics are interrelated. Another thing that would have been helpful here is to clarify whose perspective we would have with regards to the data available (i.e., an informed research or EPA scientist, a risk assessor with access to confidential manufacturer information, etc.). There were quite different evaluations of some elements, such as the production volumes apparently based on assumptions about what information would be available to the person doing the risk assessment and if they would have access to confidential information; I made this judgment based on the "why" description for the prioritization exercise.
24. I do not see additional elements that would be beneficial. In fact, the list of factors is quite lengthy and while these may apply to nanomaterials in general, it would be beneficial to pare the list to something more reasonable.

2. For the prioritization process, did you find that including MWCNT-specific Influential Factors allowed you to add more detail to explain what could be important to research about the areas of the CEA you prioritized? Do you have specific suggestions about how the Influential Factor portion of the prioritization process could be improved, or about additional types of Influential Factors that would be beneficial to include?

Participant responses:

1. I think that having MWCNT-specific Influential Factors worked very well and I do not have specific suggestions.
2. Although the list of Influential Factors has some relevance to assessing the potential risk, the process of "checking off" those factors that could be relevant was probably more subjective than would have been desired. Additionally, responding to the extensive list of potential factors and elements within those factors contributed to a cumbersome process, which may have hindered getting thoughtful and useful comments from persons knowledgeable in specific areas of science. See response to question #4 regarding an alternative prioritization process.
3. For the MWCNT-specific influential factors, I found the selection to be very comprehensive, perhaps almost overwhelmingly comprehensive to the point that it was difficult to sort through all of them. It is hard for me to suggest a better way of doing it though, as with this many factors it can be hard to narrow them down. Perhaps some sort of design of experiments or critical path analysis would help this process run even better and help narrow down what should be worked on and what would be nice to work on.

4. Absolutely. The Influential Factors identified were critical to for helping prioritize research needs. I believe this area was very thorough and can't think of any factors that were missed.
5. I did find that the Influential Factors allowed me to add more detail but they are quite burdensome to have to go through >70 factors.
6. Yes, I felt the MWCNT-specific Influential Factors allowed me to explain what I had to say. No suggestions for improvement.
7. Generally, I found the Influential Factors to help provide more detailed responses. I sometimes found that the factors were difficult to interpret in the various different contexts of the different elements. I think it may be beneficial to have a more tailored list of influential responses for the different types of elements. For example, in the Impacts section, the "Analytical Technology" influential factor could either refer to analytical technologies characterizing the biological responses or the chemistry of the ENMs in the biological assays.
8. Also see response to Q2. I did not find that the Influential Factors were useful in the prioritization process. After reviewing the overall results, it is not apparent how the factors were used.
9. It was fine; no improvements needed.
10. The influence factors did not seem to be used in subsequent phases of the process after first identification. Perhaps they are useful for prioritization of research that addresses multiple risks using similar technology. Perhaps live workshop discussions will reveal commonality or differences in interpretation of Influence Factors by individuals.
11. Response: I thought there were too many, and often redundant, factors to evaluate.
12. It was useful, but I don't have suggestions for improvement.
13. I probably found these of least use due to the fact that they were very generic and were not easily summarized in the reports from Rounds 1 and 2. I think I would have preferred to have been prompted to state in the "Why?" text what the influential factors were (which I did in most comments made) as this is both easier on the writer and easier on the reader as the factors can be seen in context.
14. No.
15. The multiple sub-categories that were active if one selected "Important" and "Not Confident" was onerous and did not seem to contribute much to the understanding or the prioritization.
16. Some of the questions are not clear and some have too much overlap. I hope there are more guidelines on how to answer some of the questions.
17. Q1: Yes. Q2: No.
18. Q1: No. Q2: No.
19. The specific influence factors did allow for the opportunity to expand more detail about the MWCNT review, although the format could potentially be changed to something more user-friendly such as a checklist that is separate from the document and does not require scrolling over within the spreadsheet.
20. Some Influential Factors used here didn't match with given environmental conditions. For a study similar to this (i.e., nanomaterial toxicity study), in addition to the five categories (Product Life Cycle, etc.) presented, physiological responses and fate and transport (F&T) in the plasma might need to be considered for the toxicology assessment to be complete.
21. I did not find the Influential Factors very helpful. I struggled to fill them in and then it seemed that many others did not fill them in. So in the review cycles I was not able to see if they were useful in modifying my opinions.
22. Yes, including the MWCNT-specific Influential Factors was very useful.
23. I think more information is necessary to describe the purpose of the influential factors. One question I had was influential compared with regards to what? I would give different answers if the question was influential with regards to why I am not confident about the availability and utility of the current data for assessing risk, what I think are the Influential Factors are with regards to the effects or behaviors for an Element/RRF pair, or why I think this is important to assessing the risk. That had me unclear how to answer whether something was influential or not. Also, some of the Influential Factors could have been redundant such as selecting "bioaccumulation" if the element was bioaccumulation or "soil" for terrestrial biota. The huge number of potential Influential Factors was somewhat overwhelming and made each element that required choosing all of the Influential Factors to take four or five times longer than those that did not require choosing the Influential Factors and was thus a minor disincentive.
24. The framework is good in that it focuses attention on what needs to be addressed—or at least considered. I do not see the need for additional

3. Are the data (i.e., bar charts, data tables, and matrices) from each prioritization round clearly conveyed? Were the collated responses from the group helpful in carrying out prioritization a second time? Do you have specific suggestions for improving how prioritization data are reported?

Participant responses:

1. I do think that the data were clearly conveyed once I took the time to read and go through the data, but I must admit that I got a bit of a feeling of “data overload” when first opening the collated responses.
2. All the bar charts, data tables, and matrices were useful, but because they contained so much information (sometimes requiring an increase in magnification to read text) they were not as informative as would be desired. I would suggest that a “narrative” summarizing the results be prepared and accompany each bar chart, table, etc.
3. I think overall, yes, the data conveyance method worked, but it’s a lot of information to digest since it is broken down so many ways and one could easily spend days just looking through all the bar charts and trying to put them into meaning. However, I found the charts from the second prioritization round more informative as they quickly summed up the biggest issues (those in the red boxes) and those percentages helped give insight on the peer review consensus, which tended to be somewhat consistent on what issues the majority felt were the most important. So I think the process worked. It seemed cumbersome at the time, but I think the results it yielded are useful, even if I’m sure the target application is incorrect (see my answer to charge question #4 below).
4. I liked the way the results for each round were summarized and presented; they definitely helped me compare my results to the rest of the group during the second round of prioritization. A verbal summary of main findings would have been useful.
5. The data were clearly conveyed and the data were useful during the second prioritization. My only suggestion would be to again reduce the number of graphs. I understand that this will be difficult but may be accomplished by reducing some of the Influential Factors since they were quite excessive. The results interpretation Webinar was very useful to quickly understand what all of the data meant and what was useful for the Round 2 prioritization and what was not.
6. I think the data were clearly conveyed, although I would have appreciated more visual data throughout the text. I felt the collated responses were helpful in the second round of prioritization, as it led me to specific areas of the document that I wanted to consider in further detail to see if I had potentially missed something that others found important. In some ways I used these data to improve my recommendations/prioritizations. In some ways, I kept my original thoughts intact, despite the results from the group.
7. When I received the results from the prioritization rounds, I felt overwhelmed by the data. With the help you provided, I was able to wade through it slowly, but I think there could have been a better way to package the data in a more user-friendly way.
8. Too many charts. Colors not always clear on the charts. Too much detail for the initial prioritizations that required so many charts with information that added little to the process. If the first round had focused on the high level issues, then perhaps the RR Factors would be useful in subsequent rounds. This seemed to be a “box-checking” exercise. Also, while there was the box for “WHY” Prioritization Tool, I could not find how to access that field from others so that I could not figure out why the ratings were as they were. Yes, in that it confirmed the stability of the first round. There were just a few changes in the priorities from Round 1 to 2. A few elements moved in and out of the “Red” box. This reflects, I think, that there is so much uncertainty about the actual MWCNT-polymer material that there is little confidence about what is known. I had a hard time figuring out where my own responses fit into the Matrix. For example, I rated “Product Life Cycle Raw Materials” as “Least Important.” This does not appear in the Matrix as far as I can see. I also rated “Product Life Cycle Material Processing” both Volume and Release Rate as “Possibly Important.” All I could find in the summary Matrix in the RED box was “Product Life Cycle-Material Processing-Release Rate, I: 29%; C: 25%”, which seems to indicate that 71% rate this as Possibly Important or Least Important. Why would this not have been put into one of the other boxes in the Matrix?
9. Yes. I don't know that the second round helped much. Please be sure to report the full range of responses and not just the mean.
10. The data reporting is adequate. It is apparent from the breakdowns at points the small number of representatives of certain sectors and expertise. The statistical analysis of those results as implied by the bar charts, etc. is somewhat limited by the apparent small sampling.
11. Response: I think the summary bar charts are useful, rather than detail on every single row in the worksheets.
12. It was a challenge to present the data in a large matrix even with the ability to zoom in on parts of the document.

13. At first I thought the tables etc. were dreadful and of little use, but I stuck with the approach as laid out and actually found it very interesting and of great use, especially in conveying such a large amount of complex information. The bar graphs were particularly useful in getting me to think about my answers etc. and then look for reasoning behind any deviations. I liked the "Importance/Confidence Matrix of Element-Risk Relevance Factor Pairs" as a summary figure, although I did find the text very small here and in the detailed tables and therefore with having to zoom, it became slow moving through the documents, so I tended to dip in and out of the documents as needed. I have no idea how this could be improved—it may not be possible.
14. I must admit that the data were clear, but tedious to wade through and digest. In fact I still go back and look at them when I think about this process. The results of the first round were certainly enlightening as to the different perspectives within the group. These results did help me to be more confident in some of the rankings that I was not confident in on the first round. I think there are so much data that come out of an effort like this that it is difficult to distill these more.
15. Personally, I felt that the second round was not that helpful. Given the very large uncertainty, the modest shifts that seemed to occur after the second round, I don't think it was necessary.
16. Yes. I have no additional suggestions. I am interested in seeing how things work out at the face-to-face meeting.
17. The data were clearly conveyed. The group responses did not help me for the second prioritization. For me, one round of prioritization was enough.
18. Q1: Yes. Q2: Yes. Q3: No.
19. The collated responses from the group were very helpful in reviewing the general trend in responses and the display format of graphs and charts was also useful.
20. The data in general were conveyed well, although some parts looked overcrowded. Second round responses, for my case, didn't change much from the first, although the feeling of assurance in some categories was good to have by knowing that there were some consensuses. The purpose of sharing the collated responses from the group might be achieved better by giving more time after the first round (before the second round starts) with available references. The way the questions were asked may also need to be modified. In this study case, the challenge we face is a lack of enough studies. And many of our answers were obviously reflected that way in the section where we were allowed to give reasons for our answers (i.e., insufficient data, study, etc.). If the questions were prepared in such a way that each reviewer was asked to provide supporting document(s)/articles, the prioritizing process could come up with more specific information for our next steps, although it might have taken longer.
21. With the MWCNTs exercise, I found it hard to really learn from the results from the first round. I spent much time studying all the statistical data, but it was hard to be swayed by just the little "why" column and I was not always sure if the "why" comment I found interesting was applied to the high importance category. Sometimes it was not clear what was meant by some of the comments.
22. While the data were clearly conveyed, the collated responses from the group are not useful for carrying out the second round of prioritization. It might have been more useful for some staff person to write up a summary of the responses that captured the range of arguments for each section.
23. I found them very straightforward to follow. The amount of information provided was substantial so that did make it challenging to follow anything other than one element/RRF pair at a time. Perhaps having the information also available as an Excel document would have been helpful since the headings would have been easier to follow while I scrolled through the individual boxes (i.e., with Excel, the headings and labels can always be visible, while they can be lost if zoomed in on a spreadsheet). How I used the prioritization data was to compare the rankings from everyone against mine and then only look more in depth when the rankings were substantially different. I didn't use the summary of the influential factors to review my influential factors; since I found the number of factors overwhelming, it was unclear to me what exactly the influential factors were supposed to do (see question 2). It seemed that there was a huge divergence in the responses given with most people selecting different elements and each element typically only having a small number of people who chose it.
24. The presentation of prioritization is clear. No suggestions for changes.

4. Do you have specific comments on how this prioritization process could be improved?

Participant responses:

1. No, not really
2. There is probably no one single process that can be applied across all types of prioritization processes; however, whatever process is applied should try to optimize the time provided by each person participating in the process. The current process is too cumbersome and requires an unnecessary amount of time from each participating person that could be better spent getting directly to the question of what research is needed to support future assessments and risk management decisions. I would suggest that future efforts of this type focus on developing a draft document that contains much of the same information in the decaBDE and MWCNT document but also includes a discussion of data gaps and recommendations for research. The draft document could undergo public/stakeholder review for input; a group of experts in the scientific fields of interest could be identified as expert peer reviewers and would provide recommendations on prioritizing research [expert peer reviewers would be given comments or a summary of comments from the public/stakeholders review for their consideration]. A meeting with expert peer reviewers would be optional.
3. In regards to how to improve this process, I would encourage EPA to get more subject matter experts outside traditional EPA areas involved early on to vet the underlying concept before it is sent out. It would be very worthwhile for EPA to get a better list of subject matter experts across specific technologies/applications/sciences/environmental issues to ensure that what is being looked at is truly a real potential issue. Sure, the CEA process does this…but when you put out a topic for evaluation that has a crucial flaw (see my inputs on the case study document above) it gives the wrong impression about the process. The process used to draft the case study can be important for political reasons, but it can unfortunately govern way too much of what we look at as scientists. I like the openness and transparency of the process we have with the CEA, but again, if the underlying premise of the study for a wide group of people to look at is fatally flawed, it gives the impression that the people who put together the report missed the ball… and the playing field, too. Don't get me wrong—I think looking at MWCNT emissions in a proactive manner is a great thing to be looking at, and I'm glad that this study brings out all in one place what is and is not known about MWCNT toxicity and environmental effects. But this study is looking at the wrong application, which is particularly important since application of the technology will drive exposure and environmental impact. Therefore, if this program went forward focusing on MWCNT in textile back coatings I believe it would be focusing research on the wrong problem/question to answer.
4. Include a more useful type of contaminant (likely another carbon-based nanoparticle) for comparison to MWCNTs.
5. See comments above.
6. I feel there could be more information on what is expected in each round from the people undergoing the process. I wasn't always sure that my responses and results were in line with what was expected from me during the process. I wasn't sure entering the second round if I was supposed to incorporate the rest of the group results or stick with what I had, potentially submitting the same spreadsheet (if the group results did not influence my own, for example). A little more guidance is suggested.
7. I don't have any specific comments on this.
8. I think the approach is OK, just that the underlying data and information are so uncertain and scant that the process did not provide much stratification. While the last question asks about the three most important research questions to be addressed, it might be useful to ask for the three LEAST important research questions AT THIS TIME, recognizing that the research process is iterative as more information is gained.
9. No.
10. I read all of the instructional documents, participated in the pre-process Webinar, viewed the instructional presentations, and passed the pre-test. However, despite the lucid due date timelines and reminder e-mails, it was not clear to me at each stage what exactly was being expected of me. For instance, for Round 2, I was expected to review the Round 1 responses of others, make any changes to my own responses, and resubmit the same spreadsheet (now updated) as I did in Round 1. It was not apparent to me as the Round 2 deadline approached what precisely I was to do after I reviewed the responses of other and my own Round 1 responses. Similarly, for the Round 3 Submission of Charge Questions, I had some difficultly in locating the list of questions that I am to submit. It seems to me that the CEA organizers are so steeped in the process that they have developed and are implementing that it is easy to forget that the process is new for us, the participants, and we do not necessarily already know what to do (what the deliverables are) at each step. For clarity, I would suggest that the request for information e-mails (and reminder e-mails) at each stage when input is requested from the participants make it as clear as to what is due and it has been made clear when it is due. A numbered or bulleted bold list of exactly what is requested by the pending due date would be in order along with an attachment of the

relevant form to be filled out or a hyperlink to the requested document on the CEA Web site.
11. Response: Could have started at a high level during Round 1, then only expand into Round 2 issues rated as low confidence, etc.
12. This approach is a significant advantage over just showing up at a workshop and wishing for the best.
13. One comment is that the exact requirements (deliverables) at each stage could maybe have been a little clearer. In the case of the first round it was made very clear what was wanted from us and what tools we needed to use in terms of the spreadsheet to fill out. However, it became a little less clear on the second round as to what we needed to fill out (this was answered and made clear very efficiently when I raised the question) and in the third round I wasn't exactly sure what I was supposed to supply. Perhaps providing a specific template at each stage for us to fill out would have helped. My second comment refers to the spreadsheets used in Rounds 1 and 2 and particularly the "Why?" question. Overall, if you stated that something was important you were prompted for further information (as one would expect) and also a small justification of why. However, I find that why something is considered not important can be of great interest and importance also, so I would have liked to have been prompted here also. However I can understand that this would have increased the time even further on us reviewers! Overall the approach and process thus far has been well conveyed, well reported, logical, and enjoyable and the contractor should be commended.
14. No.
15. Shorten the list, especially the secondary questions.
16. No. I am new to this process. I might be able to help more once I finished this first experience.
17. No.
18. Not at the moment. Though I do think our group could have benefited from discussions prior to the workshop either via an online forum or in person meeting. This is important work and it warrants creating better group dynamics for participants early on.
19. If there are opportunities to condense the material and make the reviewer input documentation more user-friendly (i.e., more checklists and boxes as opposed to requesting written review sections), it may improve reviewer participation.
20. Please see the response in #3.
21. [Not Answered]
22. See my response to (3) above.
23. As described above, I think more information about whose perspective this evaluation would occur from (is confidential information available or not) and a better description of what the different Element/RRF pairs are supposed to indicate might help decrease the extent to which the judgments vary based on different interpretations of the rules and intents rather than different interpretations of the science available. Personally, did not know what "abiotic" meant with regards to "exposure route" so the terms could be better defined; I did send an e-mail to inquire about this, so it was clear after that point but had not been initially.
24. It is interesting that there was some good consensus during the first round of prioritization. I suggest that the second round needs to be more interactive (i.e., face-to-face or via a series of conference calls where consensus was not reached). This would allow for better exchange of ideas rather than simply reissuing a blind document.

5. What are the top three detailed research questions that you feel should be priorities for funding in order to enable future assessments of MWCNT flame-retardant coatings applied to upholstery textiles, in support of risk-based decisions?

Participant responses to question 5 are provided in **Appendix I.1**.

Appendix I
Research Questions Submitted as Part of Charge Questions

Appendix I
Research Questions Submitted as Part of Charge Questions

I.1 Research Questions Submitted as Part of Charge Questions

The following is a list of individual research questions submitted by participants as part of the Charge Questions issued by the U.S. Environmental Protection Agency (EPA) (see question #5 under Input on Prioritization Workshop Process in **Appendix H**). Twenty-four participants submitted answers to the Charge Questions following the completion of Round 2. Each participant was asked to name his or her three most important research questions. These research questions were then used to develop the “Starter Research Question Set” used by breakout groups during the workshop (see **Section I.2**). The research questions are presented in no particular order and have only been edited as needed for providing questions in a readable, bulleted format. Note that some bullet points contain multiple sentences with question marks—this is not an error, but rather reflects the participant’s original response for one of the three research questions that he or she submitted.

1. What toxicological studies need to be conducted to evaluate the chronic respiratory and other organ (heart and other circulatory systems) effects from exposure to multiwalled carbon nanotubes (MWCNT) and to MWCNT/decabromodiphenyl ether (decaBDE)?

2. What are the variability in recovery, detection limits, and analysis of at least three different types of commercially produced MWCNTs in (1) standards and (2) embedded fabrics by three to four different methods? What is the analytical reproducibility of these analyses in round robin studies at different laboratories?

3. Knowing that inhalation of MWCNTs is a major cause of concern, it would be good to have real-time exposure data along the life cycle of the products and especially during product of the MWCNTs and the MWCNT product

4. Element-RRF pair: Human: consumer – inhalation: Are detectable quantities of MWCNTs released from flame-retardant coatings applied to upholstery textiles and if so, is the quantity of MWCNTs released capable of causing adverse toxicological effects (e.g., inflammation, fibrosis, DNA damage, increased mediator release by cells) in the lungs of rodents following inhalation exposure that would be indicative of human health effects?

5. What are the potential acute and chronic toxicity, including carcinogenic, implications of human inhalation of MWCNTs and household dusts containing MWCNTs?

6. Transport to air—can released form from textile be inhaled? At what concentration?

7. Impact of released form on environment—aquatic organisms, sediment,

8. What are the effects of MWCNT on soil ecosystems?

9. What are the effects of MWCNT on other environmental systems?

10. General fate of MWCNT in this particular use—we need fundamental data on everything from product manufacturing volume by any metric, use-volumes, use-release rates, disposal release rates, etc.

11. Exposure in the use phase—how do the applied materials migrate from the upholstery into the environment where they can be encountered by humans?

12. What is the fate of MWCNT flame-retardant coatings after application to upholstery textiles?

13. Transformation in the environment—do the MWCNT significantly transform in the environment from their state in the upholstery coating?

14. What is the bioavailability, persistence, and mobility of MWCNT in air, wastewater, and topsoil?

15. How do MWCNTs degrade in the environments where exposure is most likely to occur, and what are the human health implications of these degradation products?

16. How much potential exposure to consumers and other uses of carbon nanotubes used as a flame retardant in textiles would be estimated and in what form(s)?

17. Dose (Kinetics): What is the absorption, distribution, metabolism, and excretion (ADME) of MWCNTs? These data are absolutely essential for any meaningful ecological and human risk assessment. More specifically, what animal model(s), route(s) of exposure, length(s) of exposure, and dose(s) should be tested? What types of MWCNTs need to be tested and what tissues sampled? A lengthy discussion should be focused on the experimental design of these studies in order to obtain meaningful data.

18. What are the exposure and emissions from MWCNT textile application? At some point the MWCNT would be formulated with binders and solvents for coating of the textiles. The formulation step would require handling unbound MWCNT powder and volatile solvents. The approach devised for application would require for emissions. One approach would be dipping the textile into the formulation. Another approach would be to spray the formulation on the fabric. The spray process might be similar to paint spraying with issues associated with over-spray. A systematic program should be designed to systematically investigate various sources of airborne and settled dust sources of exposure.

19. Identify the limit of doses that will be considered safe for exposure.

20. How does MWCNT distribution in humans differ between inhalation and ingestion exposure routes? Are ADME models capable of predicting distributions for MWCNTs of different lengths?

21. What are the levels of release and exposure (human and environmental) associated with different uses/process and what are the characteristics of this exposure?

22. Understand the mechanism of toxicity and methods to reduce the toxicity of the material.

23. What is the inherent toxicity of the carbon nanotubes –(i.e., is the toxicity only from inhaling respirable forms or can ingestion or dermal exposure to carbon nanotubes cause toxic effects)?

24. Impacts: What are the long-term, chronic effects of MWCNTs in human and aquatic organisms? Can MWCNTs induce cancer in mammalian models? Can MWCNTs cause reproductive and

developmental alterations in vertebrates? Again, a detailed discussion on how these experiments should be designed is needed.

25. What are the dose-related long-term health effects associated with chronic exposure to carbon nanotubes?

26. What are the effects of MWCNT on the human body?

27. What are the human health outcomes as far as cancer, non-cancer, and reproductive development?

28. What research is needed to determine the most appropriate exposure metric (e.g., respirable mass, structure size and count) so as to be able to quantify exposures to MWCNT and MWCNT/decaBDE throughout their life cycle (including occupational and environmental)?

29. What metrology is needed to detect and quantify MWCNT precursors, end-products, co-products, and degradation products of interest in air, water, sediment, soil, and biota? [Relates to pairs 15 through 33 of the Excel Summary Tables.]

30. Under what specific conditions (polymer + formulation + other additives) will MWCNT really be used for textile back coatings to provide fire protection in furniture?

31. Will MWCNT oxidize in the environment? If the Zuo et al. (2010) stability of MWCNTs in air results describing the oxidation of MWCNT in the atmosphere are real, it could have profound implications with respect to understanding the importance of emissions into the environment. However, the reference is very suspicious. A full paper apparently was not written; I cannot find a copy in the carbon literature and the Chinese university Web site does not have a copy. The paper likely reported a blunder because a prevalent contaminant of MWCNT is amorphous carbon and the material may not have been carefully characterized during the time periods. Another aspect is that the researchers made their own chemical vapor deposition (CVD)-synthesized MWCNT and the material may have been singular. However, the work needs to be repeated with a series of exploratory experiments. If the exploratory experiments reveal any oxidation, then a more systematic research program can be developed.

32. Question: In the product manufacturing stage, what is the predominant form, purity, and potential ratio of the MWCNTs (free, functionalized, bundled, matrix bound) that are being used as fire-retardant replacements? This is a critical question that needs to be addressed since it sets the stage for the exposure routes and toxicity studies that are to follow. It is important to understand the form that the MWCNT is in during the application stage since this is what the workers will be exposed to. If the MWCNT is all functionalized it might have a different toxicity profile as compared to the original MWCNT. The same applies to whether it is bundled or matrix-bound. The presence of impurities could also affect the toxicity of the formulation.

33. Biophysicochemical characterization of engineered nanomaterials including carbon nanotubes (CNTs) has shown that there are a couple of dozen variables (i.e., properties) that can be used for toxicity assessment of each material with some levels of variance. Among these known physicochemical properties of CNTs, which physicochemical properties, as a first tier group, show statistically significant levels of correlations with detrimental post-exposure outcomes after reasonable period of exposure at realistic levels of concentrations in both occupational and ambient settings with minimal variance?

34. How does MWCNT surface chemistry affect toxicity?

35. The actual MWCNT that will be used in flame-retardant materials should be subjected to an initial comprehensive battery of environmental and toxicity screening assays. Results from such assays will allow follow-up of specific issues with the actual flame-retardant materials. Special attention should be given to water-borne disposal and the potential for further distribution of MWCNTs and related entities through sewage treatment systems. The impact on sewage treatment systems (in terms of potential bactericidal activity) and possible impact on agricultural systems through the distribution of sludge should also be considered.

36. What role do the various shapes, forms, and other physicochemical attributes of carbon nanotubes play on the potential for exposure and toxicity

37. Among the physicochemical properties identified as the "first tier" group in the first question (Question #1 above), which properties (or combination of the properties) facilitate more on the passage of CNTs through alveolar, vascular, cell, and nuclear membranes? And how well can the extent of facilitation processes be expressed in a quantitative way for building a new experimental model that can be customized only for CNT risk assessment and management?

38. What research is required to determine what physical/chemical modifications of MWCNT (e.g., functionalization, surface coatings, tube and agglomerate size) minimizes their toxicological properties for humans and the environment?

39. What is more hazardous—bundled CNTs or single CNTs—or is it always situation/scenario/organism-dependent?

40. Complete characterization of the MWCNT-polymer material that is applied to textiles for physical, chemical properties, purity, solubility in various media, etc., as well as characterizing the extent of release of MWCNTs or related entities from the polymer and/or the textile under what is expected to be routine manufacturing and use.

41. Question: What is the toxicity profile of the predominant form of MWCNT that the workers are being exposed to? This addresses the second component of the risk assessment equation and is related to the answers generated in the first two questions. It is critical to know the toxicity potential for the predominant material (as identified above) in the different test assays. To make this a more focused and useful question, it is essential that the toxicity testing is conducted with the appropriate form of the MWCNT. While most of the testing to date has been done on the original MWCNTs, if in actual practice the MWCNTs are functionalized or remain bundled, the results may be significantly different. It is also important to use test concentrations that are related to actual exposure potential. Since workers should be exposed to the highest concentrations, the results would identify whether additional work is required to address consumer and general public concerns.

42. Which physicochemical properties (or combination of the properties) and physiological conditions along the enteric systems in our body influence most (more or least) on the passage of the CNTs through the luminal surfaces of the GI tracts (i.e., CNT passage from luminal surface to blood stream)?

43. What scenarios in the full life cycle assessment of MWCNTs (e.g., the production process, use, or disposal) could result in sufficient quantities of substances (precursors, end-products, co-products, degradation products) being released into the environment to pose quantifiably unacceptable risk to ecological receptors? [Relates to pairs 43–48 of the Excel Summary Tables.]

44. Product Life Cycle: What is the volume and release rate of MWCNTs as related to their use as flame retardants in upholstery textiles?

45. Mobility and bioavailability throughout the life cycle of the product and different media.

46. What amount of MWCNT is released from a product with upholstery textile containing MWCNT n the course of the expected product lifetime under normal use (e.g., 20 years) as determined through, for example, accelerated aging? This might be determined through measurement of amount released or, similarly, through measurement of fraction of initial quantity not released, which may be a more practical measurement.

47. Identify the different paths that will expose workers involved in the preparation of MWNTs to the materials. Carefully study the effect of the exposure paths on the toxicity responses in animal models.

48. Question: What is the expected level of the predominant MWCNT (as identified in Q1) that the workers are being exposed to in the ambient air in the manufacturing facility? It is expected that the workers in the occupational setting will be exposed to higher levels of the MWCNTs than consumers and the general public and that the predominant risk will be through inhalation. Since the risk evaluation is based on exposure and toxicity, this part of the equation is essential to the risk assessment process. For example, if the MWCNT is present only in the bundled form and does not remain in the air, then the risk of exposure would be relatively small.

49. How much and what form of carbon nanotubes are workers exposed to when manufacturing the carbon nanotubes and incorporating them into the textile as a flame retardant?

50. Element-RRF pair: Human – Non-cancer: What are the inflammatory and pro-fibrogenic effects of MWCNTs (i.e., as defined by stimulation of lung collagen, pathological evaluation of lungs, production of pro-fibrogenic mediators by lung cells) generated from flame-retardant upholstery textile coatings in the lungs of rodents and how does this effect compare with the reported inflammatory and pro-fibrogenic activity of manufactured MWCNTs prior to incorporation into a flame-retardant coating?

51. What is the form of the released MWCNT flame-retardant coatings and how does their fate differ from pristine MWCNT?

52. What are the carcinogenic effects of MWCNTs (i.e., as defined by DNA damage, tumor promotion) within the lung or at the pleural surface (i.e., mesothelioma) generated from flame-retardant upholstery textile coatings in the lungs of rodents compared to the relative carcinogenicity, if any, of manufactured MWCNTs prior to incorporation into a flame-retardant coating?

53. Can initial MWCNT material characterization provide insight into the impact of the final flame-retardant coating? Do the characteristics of the initial MWCNT material impact the final flame-retardant coating characteristics and, if so, what characteristic of the MWCNTs is most important about the initial MWCNT material in determining the properties of the flame-retardant coating?

54. Effects: What are the human health effects of exposure to MWCNTs in real-world environments and media (i.e., after release from the coating and subsequent transformations), and is this substantially different from effects of pure MWCNTs in the laboratory setting?

55. How do the bioavailability and toxicity of released MWCNT flame-retardant coatings compare with what we know about pristine MWCNT?

56. How does the volume of MWCNTs in a product impact the release rate of MWCNTs from MWCNT flame-retardant coatings? Specifically, how can the volume of the material released from the flame retardant coating be simulated in a laboratory setting to provide accurate measures of release volumes?

57. Development of rapid, cost-effective detection technology for laboratory and field work for MWCNTs and related entities. At present, the ability to detect and measure MWCNTs requires equipment not often found in laboratories and is expensive. Careful sample preparation is needed in some cases and the ability to measure/monitor in diverse media is limited.

58. Can realistic dose volumes and kinetics of MWCNT release rate be used to develop human exposure rate studies to provide more realistic exposure scenarios for consumers from start to end of product lifetime?

59. Assuming one or more plausible scenarios exist that could pose unacceptable risk to ecological receptors, what modifications of established effects tests are needed to provide credible evidence of safety for ecological receptors? [Relates to pairs 66 through 73 of the Excel Summary Tables.]

60. Release rate of MWCNT during product manufacturing, product use, and disposal/recycling of the product?

61. Over the lifetime of a MWCNT flame-retardant coated product, what is the airborne release of MWCNTs?

62. What amount of MWCNT is released into the air (escapes) through controls likely to be in place in MWCNT flame-retardant upholstery textile coating manufacture? Or alternatively, what control (e.g., filter type/pore size) is required for use in likely environment of MWCNT flame-retardant upholstery textile coating manufacture to reduce MWCNT release to below detectable limits (~prevent release)?

63. What are the rates of MWCNT release from fabrics (coated versus embedded) during OECD standard washing machine test scenarios, including multiple washings? Does this differ for commercially-produced MWCNTs synthesized by different methods (e.g., CVD versus arc discharge)? Does this differ over time as fabrics undergo mechanical wear or exposure to sunlight?

64. Release from textile matrix—how much, over what time, under what conditions, in what form

65. What amount of MWCNT is released from a product with upholstery textile containing MWCNT at the end of the product life in the period between its normal use, such as the couch in the living room or the seat in the car, to its final disposal such as buried in a landfill or burned in an incinerator? Once buried, it is very unlikely that that the MWCNT in the textile coating will pose a risk due to its inherent immobility. The dismantling of the product and exposure of the components, for instance the underside of the treated fabric, may present the opportunity for release of MWCNT in a less controlled environment than in place during the product's manufacture. Shredding of the material or incineration of the textile material at the end of the product's life may present some of the most significant opportunities for MWCNT release of the entire life cycle of the MWCNT.

66. What is the release rate of particles containing MWCNT from textiles? The understanding of shedding of nanomaterials from products during use is not well-established. The lifetime of the furniture may be decades long and during the service of the product, MWCNT would be released from the fabric. It is likely that the released particles would accumulate in the dust in the indoor environment. A protocol needs to be developed to accelerate the life of the release of MWCNT particles from textiles. This might use some standard tests for flexure, rubbing, etc., with airborne particle measurement. This type of test is empirical; however, it might be a way to compare different formulations and different fabrics under a number of scenarios.

67. Quantification of the exposures to MWCNT flame-retardant coatings applied to upholstery textiles in occupational and non-occupational consumer settings using various relevant exposure metrics.

68. Identify the determinants of exposure to MWCNT flame-retardant coatings applied to upholstery textiles.

69. Conduct occupational risk assessment and identify specific tasks/operations in industry that face higher risks, and sensitive sub-populations in consumer populations.

70. What are the long-term risks of low MWCNT concentrations to humans and ecological receptors?

71. What analytical techniques can measure MWCNTs at sufficiently low concentrations in relevant biological and environmental media, what are the detection limits for those techniques, and can they identify if the MWCNTs are individually available or attached to polymeric substances?

72. To what extent will MWCNTs be removed during wastewater treatment plants and what factors are most important with regards to the removal rates?

I.2 Starter Research Question Set

The following Starter Research Questions were formed from the previously listed research questions (see **Section I.1**) in order to be used by the breakout groups during the workshop. For a list of the breakout groups, the participants in each breakout group, and the list of E-RRF pairs assigned to each breakout group, please see **Appendix J**.

Breakout Group 1 Starter Research Questions

1. What toxicological studies need to be conducted to evaluate the chronic respiratory and other organ (heart and other circulatory systems) effects from exposure to MWCNT and to MWCNT/decaBDE?
2. What are the potential acute and chronic toxicity, including carcinogenic, implications of human inhalation of MWCNTs, and household dusts containing MWCNTs?
3. How much potential exposure to consumers and other uses of carbon nanotubes used as a flame retardant in textiles would be estimated and in what form(s)?
4. Dose (Kinetics): What is the ADME of MWCNTs? These data are absolutely essential for any meaningful ecological and human risk assessment. More specifically, what animal model(s), route(s) of exposure, length(s) of exposure, and dose(s) should be tested? What types of MWCNTs need to be tested and what tissues sampled? A lengthy discussion should be focused on the experimental design of these studies in order to obtain meaningful data.
5. Identify the limit of doses that will be considered safe for exposure.

6. How does MWCNT distribution in humans different between inhalation and ingestion exposure routes? Are ADME models capable of predicting distributions for MWCNTs of different lengths?
7. Understand the mechanism of toxicity and methods to reduce the toxicity of the material.
8. What is the inherent toxicity of the carbon nanotubes –(i.e., is the toxicity only from inhaling respirable forms or can ingestion or dermal exposure to carbon nanotubes cause toxic effects)?
9. Question: What is the toxicity profile of the predominant form of MWCNT that the workers are being exposed to? This addresses the second component of the risk assessment equation and is related to the answers generated in the first two questions. It is critical to know the toxicity potential for the predominant material (as identified above) in the different test assays. To make this a more focused and useful question, it is essential that the toxicity testing is conducted with the appropriate form of the MWCNT. While most of the testing to date has been done on the original MWCNTs, if in actual practice the MWCNTs are functionalized or remain bundled, the results may be significantly different. It is also important to use test concentrations that are related to actual exposure potential. Since workers should be exposed to the highest concentrations, the results would identify whether additional work is required to address consumer and general public concerns.
10. Element-RRF pair: Human – Non-cancer: What are the inflammatory and pro-fibrogenic effects of MWCNTs (i.e., as defined by stimulation of lung collagen, pathological evaluation of lungs, production of pro-fibrogenic mediators by lung cells) generated from flame-retardant upholstery textile coatings in the lungs of rodents and how does this effect compare with the reported inflammatory and pro-fibrogenic activity of manufactured MWCNTs prior to incorporation into a flame-retardant coating?
11. Effects: What are the human health effects of exposure to MWCNTs in real-world environments and media (i.e., after release from the coating and subsequent transformations), and is this substantially different from effects of pure MWCNTs in the laboratory setting?
12. Can realistic dose volumes and kinetics of MWCNT release rate be used to develop human exposure rate studies to provide more realistic exposure scenarios for consumers from start to end of product lifetime?

Breakout Group 2 Starter Research Questions

1. Exposure in the use phase—how do the applied materials migrate from the upholstery into the environment where they can be encountered by humans?
2. How much potential exposure to consumers and other uses of carbon nanotubes used as a flame retardant in textiles would be estimated and in what form(s)?
3. Dose (Kinetics): What is the ADME of MWCNTs? These data are absolutely essential for any meaningful ecological and human risk assessment. More specifically, what animal model(s), route(s) of exposure, length(s) of exposure, and dose(s) should be tested? What types of MWCNTs need to be tested and what tissues sampled? A lengthy discussion should be focused on the experimental design of these studies in order to obtain meaningful data.
4. Identify the limit of doses that will be considered safe for exposure.
5. How does MWCNT distribution in humans differ between inhalation and ingestion exposure routes? Are ADME models capable of predicting distributions for MWCNTs of different lengths?
6. What is the inherent toxicity of the carbon nanotubes –(i.e., is the toxicity only from inhaling respirable forms or can ingestion or dermal exposure to carbon nanotubes cause toxic effects)?

7. Question: What is the toxicity profile of the predominant form of MWCNT that the workers are being exposed to? This addresses the second component of the risk assessment equation and is related to the answers generated in the first two questions. It is critical to know the toxicity potential for the predominant material (as identified above) in the different test assays. To make this a more focused and useful question, it is essential that the toxicity testing is conducted with the appropriate form of the MWCNT. While most of the testing to date has been done on the original MWCNTs, if in actual practice the MWCNTs are functionalized or remain bundled, the results may be significantly different. It is also important to use test concentrations that are related to actual exposure potential. Since workers should be exposed to the highest concentrations, the results would identify whether additional work is required to address consumer and general public concerns.
8. Product Life Cycle: What is the volume and release rate of MWCNTs as related to their use as flame retardants in upholstery textiles?
9. What amount of MWCNT is released from a product with upholstery textile containing MWCNT in the course of the expected product lifetime under normal use (e.g., 20 years) as determined through, for example, accelerated aging? This might be determined through measurement of amount released or, similarly, through measurement of fraction of initial quantity not released, which may be a more practical measurement.
10. Effects: What are the human health effects of exposure to MWCNTs in real-world environments and media (i.e., after release from the coating and subsequent transformations), and is this substantially different from effects of pure MWCNTs in the laboratory setting?
11. How does the volume of MWCNTs in a product impact the release rate of MWCNTs from MWCNT flame-retardant coatings? Specifically, how can the volume of the material released from the flame-retardant coating be simulated in a laboratory setting to provide accurate measures of release volumes?
12. Can realistic dose volumes and kinetics of MWCNT release rate be used to develop human exposure rate studies to provide more realistic exposure scenarios for consumers from start to end of product lifetime?
13. What amount of MWCNT is released into the air (escapes) through controls likely to be in place in MWCNT flame-retardant upholstery textile coating manufacture? Or alternatively, what control (e.g., filter type/pore size) is required for use in likely environment of MWCNT flame-retardant upholstery textile coating manufacture to reduce MWCNT release to below detectable limits (~prevent release)?
14. What amount of MWCNT is released from a product with upholstery textile containing MWCNT flame-retardant at the end of the product life in the period between its normal use, such as the couch in the living room or the seat in the car, to its final disposal such as buried in a landfill or burned in an incinerator? Once buried, it is very unlikely that that the MWCNT in the textile coating will pose a risk due to its inherent immobility. The dismantling of the product and exposure of the components, for instance the underside of the treated fabric, may present the opportunity for release of MWCNT in a less controlled environment than in place during the product's manufacture. Shredding of the material or incineration of the textile material at the end of the product's life may present some of the most significant opportunities for MWCNT release of the entire life cycle of the MWCNT.

Breakout Group 3 Starter Research Questions

1. What are the effects of MWCNT on other environmental systems?
2. What are the bioavailability, persistence, and mobility of MWCNT in air, wastewater, and topsoil?
3. Impact of released form on environment—aquatic organisms, sediment,
4. What are the effects of MWCNT on soil ecosystems?
5. Will MWCNT oxidize in the environment? If the Zuo et al. (2010) stability of MWCNTs in air results describing the oxidation of MWCNT in the atmosphere are real, it could have profound implications with respect to understanding the importance of emissions into the environment. However, the reference is very suspicious. A full paper apparently was not written; I cannot find a copy in the carbon literature and the Chinese university Web site does not have a copy. The paper likely reported a blunder because a prevalent contaminant of MWCNT is amorphous carbon and the material may not have been carefully characterized during the time periods. Another aspect is that the researchers made their own CVD-synthesized MWCNT and the material may have been singular. However, the work needs to be repeated with a series of exploratory experiments. If the exploratory experiments reveal any oxidation, then a more systematic research program can be developed.
6. Transformation in the environment—do the MWCNTs significantly transform in the environment from their state in the upholstery coating?
7. How do MWCNTs degrade in the environments where exposure is most likely to occur, and what are the human health implications of these degradation products?
8. Assuming one or more plausible scenarios exist that could pose unacceptable risk to ecological receptors, what modifications of established effects tests are needed to provide credible evidence of safety for ecological receptors?

Breakout Group 4 Starter Research Questions

1. Knowing that inhalation of MWCNTs is a major cause of concern, it would be good to have real-time exposure data along the life cycle of the products and especially during product of the MWCNTs and the MWCNT product
2. What are the exposure and emissions from MWCNT textile application? At some point the MWCNT would be formulated with binders and solvents for coating of the textiles. The formulation step would require handling unbound MWCNT powder and volatile solvents. The approach devised for application would be required for emissions. One approach would be dipping the textile into the formulation. Another approach would be to spray the formulation on the fabric. The spray process might be similar to paint spraying with issues associated with over-spray. A systematic program should be designed to systematically investigate various sources of airborne and settled dust sources of exposure.
3. What are the levels of release and exposure (human and environmental) associated with different uses/process and what are the characteristics of this exposure?
4. What scenarios in the full life cycle assessment of MWCNTs (e.g., the production process, use, or disposal) could result in sufficient quantities of substances (precursors, end-products, co-products, degradation products) being released into the environment to pose quantifiably unacceptable risk to ecological receptors? [Relates to pairs 43–48 of the Excel Summary Tables.]
5. Release rate of MWCNT during product manufacturing, product use, and disposal/recycling of the product?

6. What are the rates of MWCNT release from fabrics (coated versus embedded) during OECD standard washing machine test scenarios, including multiple washings? Does this differ for commercially-produced MWCNTs synthesized by different methods (e.g., CVD versus arc discharge)? Does this differ over time as fabrics undergo mechanical wear or exposure to sunlight?
7. Release from textile matrix—how much, over what time, under what conditions, in what form
8. What is the release rate of particles containing MWCNT from textiles? The understanding of shedding of nanomaterials from products during use is not well-established. The lifetime of the furniture may be decades long and during the service of the product, MWCNT would be released from the fabric. It is likely that the released particles would accumulate in the dust in the indoor environment. A protocol needs to be developed to accelerate the life of the release of MWCNT particles from textiles. This protocol might use some standard tests for flexure, rubbing etc., with airborne particle measurement. This type of test is empirical; however, it might be a way to compare different formulations and different fabrics under a number of scenarios.

Appendix J
Breakout Groups

Appendix J
Breakout Groups

J.1 Guidance to Participants for Development of Research Questions During the CEA MWCNT Prioritization Process

The following information was provided to participants to provide guidance in the development and generation of research questions during breakout group sessions. This "breakout group template" served as a template in which participants were guided through the process of developing detailed research questions for their group's prioritized Element-Risk Relevant Factor (E-RRF) pairs, along with other relevant information pertaining to the research-to-risk management continuum as shown in the following section. Background information regarding the development of research questions was also distributed to the participants prior to the workshop.

J.1.1 Breakout Group Template to Develop Detailed Research Questions during the CEA MWCNT Prioritization Process

Introduction: Each breakout group is assigned a select number of priority E-RRF pairs based on the outcome of the collective judgment process.

Breakout group challenge: Generate detailed, specific research questions that can be actively pursued in the research community to support future assessments and subsequent risk management decisions.

[Participants were referred to **Figure 9** in **Section 2.5.2**.]

To accomplish this challenge, remember the following tools:

- Your group members.
- Influential factors and "why" answers associated with the selected E-RRFs, compiled from all three rounds of prioritization.
- Starter research questions submitted after Round 2 of prioritization that are associated with the selected E-RRFs. Table of example risk management decisions (see **Table J-1**).
- Table of example problem formulation questions (see **Table J-2**).
- Guidance for research question development (see below).
- Example tables (see below).

Table J-1. Examples of risk management decisions (U.S. EPA 2012b)*

Area of Decision-Making	Directed At	Example Decisions
Product environmental health and safety	New chemicals; Existing chemicals; Biotechnology	Pre-manufacturing notices; Pesticide re-evaluations; Permits to release genetically modified organisms
Site management	Risk avoidance; Risk mitigation; Site location	Accidental releases; Cleanup of hazardous waste landfills; Degree of contamination; presence of endangered species
Natural resource use	Habitat integrity; Species introductions	Land use (e.g., road construction, mining, agriculture, logging); Integrated pest management

Table J-2. Examples of questions for problem formulation (U.S. EPA 2012b)*

General Areas	Specific Questions
What are the characteristics of the stressor of concern?	Is the stressor of concern chemical, physical, or biological? What are the physicochemical characteristics of the stressor? What are the locations and quantities of releases of the stressor to different media?
What are the characteristics of the exposure setting?	What are the known concentrations of the stressor in different media? What processes move the stressor through the environment? How does the stressor change as it moves through the environment? What is the spatial scale over which exposures to the stressor are likely to occur?
What are the characteristics of the exposed populations?	Which individuals, populations, or population segments are expected to be exposed? Which species and trophic-level relationships are present in exposed ecosystems? What are the probable exposure routes and pathways for the population(s) of interest? Is exposure to the stressor expected to occur only during a single event or will exposures be episodic or continuous? What is the time scale over which exposures to the stressor are likely to occur?
What are the assessment endpoints?	What adverse effects have been observed in the population(s) of interest? What are the most sensitive species and measured endpoints? What processes affect the behavior of the stressor within the receptor? How does the stressor change as it moves through the receptor? What biological mechanisms are involved in the formation of adverse effects? What social conditions or impacts might result from the stressor? What economic conditions or impacts might result from the stressor? What natural resources might be affected and how? What ecosystem services might be altered and how?

* Tables J-1 and J-2 were adapted from the following source: Van Leeuwen, C; Biddinger, G; Gess, D; Moore, D; Natan, T; Winkelmann, D. (1998). Problem formulation. In G. Biddinger (Ed.), *Ecological Risk Assessment Decision-Support System: A Conceptual Design* (pp. 7–14).

<u>Guidance for developing research questions:</u>[1]

Research questions should:

- Support the Comprehensive Environmental Assessment (CEA) process (i.e., developing a research plan, conducting research, compiling new information in the CEA framework, and informing future risk management efforts) for multiwalled carbon nanotubes (MWCNT) as used in flame-retardant coatings applied to upholstery textiles.

- Describe research areas in ways that suggest the design of the research that is required to answer the question, or clearly translates into directly testable research hypotheses.

- Search out and address blind spots and gaps in scientific knowledge, by meeting the following criteria:
  - Be answerable through a realistic research design.
  - Have a factual answer that does not depend on value judgments.

[1] Adapted from W.J. Sutherland et al.'s 2011 paper in Methods in Ecology and Evolution, *Methods for collaboratively identifying research priorities and emerging issues in science and policy*.

- Address a highly prioritized research area for future risk assessment and risk management of MWCNTs (i.e., an E-RRF, associated Influential Factors (Ifs), and reasoning).
- Be of a spatial and temporal scope that could be reasonably addressed by a research team.
- Not be answerable with "it depends."
- Should not be answerable by "yes" or "no."
- If related to impact(s) and intervention(s), contains a subject, an intervention, and a measurable outcome.

Instructions:
1. Please write the name of an E-RRF pair assigned to your breakout group above **Table J-3**. This specific E-RRF pair serves as a starting point for developing a potential risk scenario (see Step 3).

2. Provide context to this E-RRF by describing a potential risk scenario that risk managers might try to avoid or mitigate for this specific E-RRF. The goal (see **Figure 9**) of carrying out activities along the research, assessments, and risk management continuum is then to mitigate or avoid this potential risk scenario.

3. Complete the template table for this E-RRF and associated scenario. The following questions might help in filling in **Table J-3** from left to right:

a) What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF? (See **Table J-1** for example risk management decisions.)

b) What information would you need from an assessment to support these Risk Management Decisions? (See **Table J-1** for example problem formulation questions.)

c) What type of assessment could provide this necessary information?

d) What information would enable this assessment but is currently unavailable?

e) What specific detailed research is needed to provide such information identified previously? Integrate relevant IFs to form research questions as appropriate (see "Guidance for developing research questions")?

f) What is the estimated cost of completion for this research question in U.S.$?

g) What is the estimated time frame for completion of this research question in years?

4. Include a rationale for each item in the previous row.

5. Rank the items shown in the table in order of descending importance in terms of actions to take to mitigate or avoid the potential risk presented in the E-RRF scenario (i.e., items in Row 1 would have higher risk management priority than those in Row 4).

Draft template for breakout groups:

Breakout group: ________________________ Specific E-RRF pair: ____

Describe a potential risk scenario for the E-RRF pair: ____
____
____

Table J-3. Template for developing detailed, actionable research questions

Note: The items shown in the table should be ranked in order of descending importance according to value to risk management (i.e., items in Row 1 have a higher priority than those in Row 4). Participants can use the "rationale" rows to place group discussion notes related to the rationale for each question.

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1							
Rationale							
2							
Rationale							
3							

	Risk Management	Informing Management	Assessment	Informing Assessment	Research	Estimated Finances ($)	Estimated Time Frame (Years)
Rationale							
4							
Rationale							

Example 1:
Specific E-RRF pair: Impacts—Aquatic Biota—Survival
Describe a potential risk scenario for the E-RRF pair: Decreased survival of fish populations due to MWCNT released from wastewater treatment plants.

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?

	Risk Management	Informing Management	Assessment	Informing Assessment	Research	Estimated Finances ($)	Estimated Time Frame (Years)
1	Concentration at which to establish a maximum contaminant level.	Predicted Environmental Concentration (PEC)/ Predicted No Effect Concentration (PNEC)	Ecological risk assessment	Kd—partitioning coefficient of MWCNT	What is MWCNT partitioning behavior in estuarian systems?	$200K	3 years
Rationale	Participants can use the rationale rows to place group discussion notes related to the rationale for each question.						

Example 2:

<u>Specific E-RRF pair:</u> Exposure Route— Human: Occupational— Dermal

<u>Describe a potential risk scenario for the E-RRF pair:</u> MWCNT adsorb to cotton gloves worn by workers producing them and are then exposed to the MWCNT and associated metal contaminants when the gloves touch other parts of their body (e.g., eyes).

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Determine the type of PPE that would mitigate worker dermal exposure.	What type of gloves do not adsorb MWCNTs?	Occupational exposure assessment	Adsorption behavior of MWCNT on different types of glove materials	Do MWCNT adsorb to latex gloves?	$100K	2 years
Rationale	Participants can use the rationale rows to place group discussion notes related to the rationale for each question.						
2	Determine the type of PPE that would mitigate worker dermal exposure.	What type of gloves do not adsorb MWCNTs?	Occupational exposure assessment	Adsorption behavior of MWCNT on different types of glove materials	Does the type of metal catalyst used to manufacture MWCNTs influence adsorption behavior of the material to different types of gloves (e.g., latex, cotton)?	$300K	5 years
Rationale							

Example 3: ***This is a non-desirable example (i.e., the type of example participants should aim to avoid).***
Specific E-RRF pair: Exposure Route— Human: Occupational— Dermal

Describe a potential risk scenario for the E-RRF pair: MWCNT adsorb to cotton gloves worn by workers producing them and are then exposed to the MWCNT and associated metal contaminants when the gloves touch other parts of their body (e.g., eyes).

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Gather as much research as possible to better understand MWCNT effects on workers.	Everything possible about dermal exposure of MWCNT to workers	Any type of exposure and toxicity assessments	All types of parameters relevant for exposure and toxicity assessments	Variety of questions such as: What are the toxicological consequences?	More than $1000	More than 3 years
Rationale	Participants can use the rationale rows to place group discussion notes related to the rationale for each question.						
2	Determine if worker eye color influences exposure to MWCNT in workplace settings.	Relationship or mechanism behind eye color influences on worker dermal exposures to MWCNT	Toxicity assessment and epidemiological studies	Epidemiological studies	What is the No observable adverse effect level (NOAEL) for people with different eye colors?	Between $1–5K	Between 1–10 years
Rationale							

J.2 Methodology for Assigning Participants to Breakout Groups

The 15 most commonly agreed upon prioritized E-RFF pairs generated from the results of Round 3 (see **Appendix C.4** for further details) were addressed in detail by breakout groups, with the purposes of generating actionable research questions and illuminating the connection between the necessary research, the assessments this research would support (e.g., human health risk assessment, ecological risk assessment, life cycle assessment), and ultimately, the risk-management decisions those assessments would inform.

Participants were assigned to breakout groups after the final E-RRFs were determined (subsequent to Day 1 of the workshop). The workshop participants were divided into these 15 prioritized E-RRF pairs based on their areas of expertise in accordance to the specific E-RRF area. This division of participants into the breakout groups occurred on-site. To ensure that the breakout groups operated in the most efficient manner possible, the decision regarding how many E-RRF pairs (in order to generate actionable research questions) were assigned to individual breakout groups was made on-site following the first day at the workshop.

J.3 Detailed Results from Round 3 Breakout Groups

Table J-4 shows the distribution of workshop participants within each breakout group, along with their assigned E-RRF pairs. The breakout groups were each assigned three or four E-RRF pairs during the workshop, which were chosen from the 15 most agreed-upon prioritized E-RRF pairs from Round 3 of the CEA Prioritization Process. The breakout groups were formed so participants could develop detailed, actionable research questions for each of their assigned E-RRF pairs.

Table J-4. Breakout groups, showing participant identifier and areas of expertise, along with the groups' assigned E-RRF pairs

Group	Participant identifier	Areas of expertise	E-RRF pairs
1	4	Human health effects	• Human – Non-cancer • Human – Occupational – Inhalation • Human – Metabolism • Human – Excretion
	21	Human health effects	
	8	Human health effects	
2	35	Human health effects	• Air – Persistence • Air – Mobility • Human – Absorption • Disposal/Recycling – Volume
	28	Exposure & dose	
	6	Ecological effects	
	1	Ecological effects	
3	11	Env. TT&F	• Wastewater – Persistence • Wastewater – Mobility • Sediment – Persistence
	31	Env. TT&F	
	3	Ecological effects	
4	19	Manufacturing	• Product Manufacturing – Release Rate • Use – Release Rate • Disposal/Recycling – Release Rate • Material Processing – Release Rate
	34	Material characterization	
	30	Risk assessment	

J.4 Formation of Detailed, Actionable Research Questions by Breakout Groups

Tables J-5, **J-6**, **J-7**, and **J-8** show the detailed, actionable research questions developed by each breakout group along with the other relevant information that pertains to the research-to-risk management continuum in the breakout group template (see **Section J.1.1**). See **Table J-4** for a distribution of participants and their areas of expertise within each breakout group and their assigned E-RRF pairs. The research questions developed by each group were ranked in order of importance by the breakout groups, except for Group 2, which stated that its research questions were not listed in any particular order of prioritization. It should be noted that any blank cells in the tables indicate that the breakout group did not complete this section of the template.

For the presentations made by the breakout groups on the final day of the workshop, see **Appendix L**. In addition, **Appendix F.1** provides an overview of comments, questions, and discussion points associated with each breakout group presentation at the workshop.

Table J-5. Completed breakout group template for Breakout Group 1

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
E-RRF Pair: Human – Non-cancer			**Scenario:** The MWCNT used in the upholstery application ("coated" or "functionalized") causes non-cancer effects after either acute or chronic exposures.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Ban the material outright if not proven safe.	Safe exposure limits for consumers or workers	NOAEL or LOAEL for the relevant material to be used in consumer or occupational exposure scenarios	Rodent toxicity data with exposure relevant material	**Conduct acute and chronic rodent bioassay studies after inhalation exposure at relevant doses using well-characterized material.**	$2M for 2-year rodent bioassay including an additional year for setup and analysis	3 years
2	Ban the material outright if not proven safe.	Safe exposure limits for susceptible individuals	NOAEL or LOAEL for the relevant material to be used in consumer or occupational exposure scenarios for susceptible populations	Rodent toxicity data with exposure relevant material in susceptible populations	**Perform experiments to test impacts of exposure on immune-compromised individuals.**	$1M	3 years
E-RRF Pair: Human: Occupational – Inhalation			**Scenario:** Workers inhale the relevant material during any part of the manufacturing process.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Ban the material outright if not proven safe.	Safe exposure limits for consumers or workers.	NOAEL or LOAEL for the relevant material in occupational inhalation exposure scenarios	Rodent data with exposure relevant material	**Acute and chronic rodent bioassay studies after inhalation exposure at relevant doses of well-characterized material**	$2M for 2-year rodent bioassay including an additional year for setup and analysis	3 years

2	Engineering controls and personal protective equipment	Safe industrial exposure limits for workers	Comprehensive occupational exposure assessment	Impact of co-factors (e.g., solvents, resins) on inhalation exposure	**Analytical and rodent studies to examine effect of co-factors on particle size, deposition , translocation, and removal**	$2M for 2-year rodent bioassay including an additional year for setup and analysis	3 years
E-RRF Pair: Human – Metabolism			**Scenario:** The relevant MWCNT material degrades to a more or less toxic metabolite after absorption, inhalation, or ingestion.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Implement appropriate control technology based on risk assessment.	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Degradability of the relevant MWCNT material compared to original MWCNT	**Develop analytical techniques for measuring the original MWCNT or metabolites in cells.**	$275K	2 years
2	Implement appropriate control technology based on risk assessment.	Half-life of relevant MWCNT material in rodents	Occupational or consumer risk assessment	Degradability of the relevant MWCNT material compared to original MWCNT	**Measuring the original MWCNT or metabolites in tissues after whole-body inhalation exposures**	$500K	2 years
E-RRF Pair: Human – Excretion			**Scenario:** The relevant MWCNT material is bioaccumulated in the body after exposure and is not excreted.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Implement appropriate control technology based on risk assessment.	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Fate of relevant MWCNT material compared to original MWCNT in rodents	**Perform experiments in rodents after exposure to determine fate and clearance of MWCNT.**	$500K	3 years
2	Implement appropriate control technology based on risk assessment.	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Level of by-products in the body	**Develop tracer methodology to detect excretion by-products of the relevant MWCNT material.**	$300K	2 years

Table J-6. Completed breakout group template for Breakout Group 2*

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
E-RRF Pair: Air – Persistence			**Scenario:** • CNTs released into atmosphere: (1) occupational (2) ambient • Longer atmospheric residence times increase probability of exposure.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Reduce atmospheric residence time.	Measure atmospheric residence time.	Risk assessment based on quantitative experimental data	Physical/chemical characterization of particles	**Develop model to predict atmospheric residence time as a function of CNT particle characteristics (QSAR).**	$500K	3 years
2	Increase propensity to aggregate.	Determine particle characteristics that dictate adverse health effects.	Human health risk assessment	Meteorological properties of atmosphere	**Determine CNT properties and meteorological properties that increase aggregation rate and decrease residence time.**	>$1M	5 years
3	Consider moratorium on nanotube production and use.	Consider economic consequences of having or not having a moratorium.	Benefit/cost analysis	Market analysis	**Develop new methods or instruments to improve CNT quantification in air (determine # or mass of CNT/m3).**	$2M	3 years
					Apply conventional benefit/cost analysis procedures.	$200K	1 year

	E-RRF Pair: Air – Mobility		Scenario: • CNTs released into ambient atmosphere • Mobility dictates extent of exposure.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Minimize mobility.	Measure extent of atmospheric mobility.	Risk assessment based on quantitative experimental data	Physical/chemical characterization of particles	**Develop model to predict extent of mobility as a function of CNT particle characteristics (QSAR) for near-field and long-distance transport.**	$1M	3 years
2	Minimize retrainment.	Determine particle characteristics that dictate adverse health effects.	Human health risk assessment	Meteorological properties of atmosphere	**Alter CNT properties or meteorological properties to increase aggregation and decrease mobility.**	>$1M	5 years
3	Consider moratorium on CNT production and use.	Consider economic consequences of having or not having a moratorium.	Benefit/cost analysis	Market analysis	**Develop new methods or instruments to improve CNT quantification in air (determine # or mass of CNT/m3).**	$2M	3 years
					Apply conventional benefit/cost analysis procedures.	$200K	1 year
	E-RRF Pair: Human – Absorption		**Scenario:** • **Humans are exposed via inhalation and ingestion.** • **Potential absorption occurs through lungs and GI tract.**				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Minimize absorption potential.	Magnitude of absorption across different tissues	Human health exposure assessment	Absorption potency as a function of particle characteristics for three representative routes of exposure	**Determine particle properties that influence extent and rate of absorption across mammalian lung epithelial tissue, GI luminal epithelia, and dermal layers.**	$5M	5 years

					Quantify extent and rate of absorption across mammalian lung epithelial tissue, GI luminal epithelia, and dermal layers. If answer is yes, then: **Maximize particle properties that decrease absorption while maintaining beneficial uses.**		
2	Consider moratorium on CNT production and use.	Determine particle characteristics that dictate adverse health effects. Consider economic consequences of having or not having a moratorium.	Occupational exposure assessment Benefit/cost analysis	Market analysis	**Rationale for this is that a group examining all three absorption processes is that you increase the potential for discovery of unique interactions among systems. While little evidence is available demonstrating dermal absorption (via abraded skin), further work should be considered because of the potential for high exposure, especially in children.**		

E-RRF Pair:
Disposal/Recycling – Volume

Scenario:
- CNTs used as flame retardants in upholstery
- Upholstery is used on furniture and accessories (e.g., curtains).
- End-of-life scenarios result in either destruction (e.g., burning), recycling, reuse, litter, or disposal in landfill.

	Risk Management	Informing Management	Assessment	Informing Assessment	Research	Estimated Finances ($)	Estimated Time Frame (Years)
1	Reduce release through return of upholstery and upholstered products to manufacturers	Quantify risk associated with aged/littered/destroyed upholstered products.	Life cycle analysis Environmental risk assessment	Disposal volume Reuse volume	**How much volume of CNTs is used in upholstery?** **How much volume of CNTs is lost from**	$100K	1 year

	through reclaim system. Consider moratorium on CNT production and use.				**upholstery during life span?** **How much volume of CNTs is lost via destruction (e.g., burning), recycling, reuse, litter, or disposal in landfill?**		

*Group 2 also developed detailed, actionable research questions for an addition E-RRF pair that they felt deserved attention in addition to their assigned E-RRFs (i.e., "Other-Social"). See **Appendix L** for reference to the presentation slides developed during breakout groups for further details regarding this additional inclusion from this group. This information was not included in the table because it was not one of their assigned E-RRF pairs selected through this prioritization process, and hence should not be included with these results that followed the prioritization process methodology.

Table J-7. Completed breakout group template for Breakout Group 3

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
E-RRF Pair: Wastewater – Persistence			**Scenario:** MWCNTs are released as either pulse industrial discharges to sewers or semi-continuous loading from industrial/commercial/residential washwater exposed to flame-retardant materials.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Regulate efficiencies of control technology that would release MWCNTs in the environment.	Will wastewater processes (activated sludge, disinfection processes) transform carbon nanotubes?	Laboratory experiments	The rate of transformation of MWCNT alone and combined in a matrix	**How does the degree of functionalization and changes in wastewater treatment processes affect the rate of transformation?**	$400,000	3 years
2	Same as 1	Tracking of MWCNT throughout the life cycle (analogous to decaBDE congeners)	Method development under control technology operating conditions	Research enables assessment of mobility of assessment within treatment plant	**How to extract and characterize MWCNT from suspended and fixed biomass or treated effluent with minimal modifications to surface group, functionalization, impregnated metals, and coatings?**	$400,000	3 years
3					**What are the transformation byproducts from MWCNT and flame resistant fibers?**	$300,000	3 years

	E-RRF Pair: Wastewater – Mobility		**Scenario:** MWCNTs are released as either pulse industrial discharges to sewers or semi-continuous loading from industrial/commercial/residential washwater exposed to flame-retardant materials.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Possible pretreatment controls by industry to prevent discharge of MWCNTs	Pilot plant, batch experiments, and modeling would predict MWCNT removal efficiency and actual MWCNT concentrations in treated effluent and biosolids.	Batch or OECD experiments Would be beneficial to have pilot tests with two or more MWCNT materials.	Distribution coefficients for some nanomaterials are available, which could be used with existing wastewater treatment plant (WWTP) models to crudely predict MWCNT removals.	**To what extent does MWCNT surface properties and incorporation into fibers affect distribution of MWCNTs between treated effluent and biosolids for different wastewater treatment plant configurations?**	$250K ($600K with pilot plant)	2.5 years (4 years with pilot)
2	Possible pretreatment controls by industry to prevent discharge of MWCNTs	Analytical techniques are required to monitor compliance, or evaluate removal in industry testing prior to approval.	Analytical chemistry method development	Detection limits of several methods exist, and may be relevant to apply given current acute toxicity test results.	**Develop extraction and/or analytical techniques to quantify MWCNTs, of diverse origin, at environmentally relevant levels in raw sewage, treated effluent, and biosolids.**	$300K ($600K)	3 years (4 years for completely new methods)
	E-RRF Pair: Sediment – Persistence		**Scenario:** Continuous deposition and burial of fiber/polymers containing MWCNT and sediments from multiple sources (air, wastewater discharge, release from whole products, hotspot with diffuse and continuous sediment, storm water)				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Regulate efficiencies of control technology that would release MWCNTs in the environment.	Is there long term persistence? Are MWCNT released from fabrics and sediments?	Laboratory experiments	There are two rates of release, rate of release from a fibers and transformation of MWCNT alone and combined in a matrix.	**How does the degree of functionalization/ changes in sediment affect the rate of transformation?**	$300,000 for 3 $600,000 for 5	3 years initially, then 5 years

2	Same as 1	Tracking of MWCNT throughout the life cycle	Method development under environmentally relevant conditions	Research enables changes over time in assessment of mobility, persistence, and bioavailability as CNTs transform in sediment.	**How to extract and characterize MWCNT from sediment with minimal modifications to surface group, functionalization, impregnated metals, and coatings?**	$400,000	3 years
3	Same as 1 and also including loadings of CNTs in fabrics	What byproducts could be formed during degradation processes and would this be impacted by the MWCNT concentration in the fabrics?	Laboratory experiments	Research enables assessment about by-product formation that may be toxic.	**What are the transformation by-products from MWCNT and flame-resistant fibers?**		

Table J-8. Completed breakout group template for Breakout Group 4

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in U.S.$?	What is the estimated time frame for completion of this research question in years?
E-RRF Pair: Material Processing – Release Rate			**Scenario:** • MWCNT are released to sewage treatment plants (STPs) resulting in exposure to environment. • MWCNT are released to air resulting in exposure to workers.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Control concentration in waste water.	Help select necessary control technologies	a) Assess release rates at manufacturing facilities. b) Evaluate release rates of different technologies: (1) Synthetic techniques (2) Filtration technologies (3) Remediation	Release rate to STP	**What is occupational exposure at current MWCNT processing facilities?**	100,000	1 year
2	Control occupational exposure in indoor air.	Help select control measures or PPE.	Evaluate exposure to workers at manufacturing facilities identifying key steps in exposure. Evaluate control/PPE measures for reducing exposure.	Release to indoor air	**What is release rate in wastewater from current MWCNT processing facilities?**	100,000	1 year
3					**Develop method (instrument) to characterize and quantify in waste liquid for monitoring.**	500,000	5 years
4					**What is the best method to capture/destroy CNT in waste liquid?**	300,000	3 years

5					**Can CNT synthesis technique reduce potential releases through control of initial raw CNT form?**	300,000	3 years
6					**What air handling technologies can be used to reduce occupational exposure?**	200,000	2 years
E-RRF Pair: Product Manufacturing – Release Rate			**Scenario:** • MWCNT are released to STPs resulting in exposure to environment. • MWCNT are released to air resulting in exposure to workers.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Control concentrations in wastewater.	Suggest manufacturing technologies and/or control technologies.	Evaluate potential release rates depending on manufacturing technique: a) Functionalization b) Dispersion c) Coating techniques	Release rate to STP (e.g., g/day) based on manufacturing technique Effect of manufacturing technique on released particle characteristics	**What is the step in manufacturing that presents most risk of release to the environment?**	$100,000	1 year
2	Control occupational exposure.	Suggest control measures or PPE.	Evaluate potential occupational exposures rates depending on manufacturing technique. a) Functionalization b) Dispersion c) Coating techniques	Release rate (e.g., mass/m3, surface area / m3, number/m3) to occupation air. Effect of manufacturing technique on released particle characteristics.	**What is the step in manufacturing that presents most risk of occupational exposure?**	$100,000	1 year
3					**How does MWNT functionalization affect the filtration efficiency and size distribution?**	$100,000	2 years
4					**How does the dispersion technique affect the filtration efficiency and size distribution?**	$100,000	2 years

E-RRF Pair: Produce Use – Release Rate			**Scenario:** MWCNT are released resulting in exposure to consumers via indoor air or the environment (via wastewater treatment).				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Regulation of acceptable matrices for use with MWNT flame retardants	Concentration in indoor air	Consumer health assessment including sensitive populations (children)	Effect of matrix on particle release	**How does particle functionalization and matrix affect aging and release to air (use accelerated weathering test), measure and quantify (number and concentration), and characterize (size distribution)?**	~$300,000	2–3 years
2	Regulation of acceptable matrices for use with MWNT flame retardants	Quantify releases to environment.	Environmental assessment	Effect of matrix on particle release	**How does particle functionalization and matrix affect release in washing product (use mini washing machines), measure and quantify (number and concentration) , and characterize (size distribution)?**	~$300,000	2–3 years
E-RRF Pair: Disposal/Recycling – Release Rate			**Scenario:** • MCNT are released during recycling for reuse (e.g., industrial shredding) resulting in release to environment (release to wastewater), resulting in exposure to environment and release to air, resulting in exposure to workers. • MCNT are released during sludge application to land, either to surface biota or humans.				
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated Finances ($)**	**Estimated Time Frame (Years)**
1	Control occupational exposure for workers in recycling facilities.	Help select control technologies or PPE.	Occupational assessment	Release rates to air from shredding	**What is the airborne release rate of MWCNT Study during shredding (e.g., form, size distribution, number, and mass concentration)?**	$100,000	1 year

2	Regulate disposal of sludge waste.	Release potential from different sludge processing.	Environmental assessment (e.g., is there enough sludge going to land that uptakes from plants, or exposure to farmers?)	Volume applied to land per year (since the release is complete to land with sludge)	**Survey of nano industry and municipal STP to gather mass of sludge per year applied to land.**	$50,000	1 yr

Appendix K
CEA MWCNT Prioritization Tool Rating Process and Materials

Appendix K
CEA MWCNT Prioritization Tool Rating Process and Materials

K.1 CEA MWCNT Prioritization Tool

The Comprehensive Environmental Assessment (CEA) multiwalled carbon nanotube (MWCNT) Prioritization Tool is a Microsoft Excel workbook that is designed to guide participants through the process of rating the CEA Framework. The tool is organized based on the Detailed CEA Framework (**Figure 4**), with a separate worksheet tab for each CEA Level. The main screens are shown in **Figures K-1** through **K-5**. On each CEA Level tab, participants provide their input using dropdown boxes or keyboard entry. Conditional formatting within Excel is used to evaluate a participant's responses and differentiate between required (yellow) and non-required (gray) inputs. The background for a required input becomes white when a valid response is entered. For example, if a participant rates an Element as "Important," that Element's Risk Relevance Factor (E-RRF) input cells for rating Importance and Confidence will change from a gray background to yellow highlighting.

K.2 Training Materials

Several types of training materials were developed to assist the participants in their use of the Tool. Text-only instructions and a glossary of terms were included on separate tabs within the Tool itself. Webinars were held to introduce participants to the CEA MWCNT Prioritization Tool, provide a demonstration of the Tool, and provide a forum for questions and answers. Additionally, training materials and other background information were made available on the CEA Nanocarbon Web site (https://ceananocarbon.rti.org/). These materials included a pre-recorded instructional video for using the Tool, a PowerPoint slideshow used in the video, and a User's Guide consisting of step-by-step instructions with screenshots of the CEA MWCNT Prioritization Tool.

K.3 Prioritization Tool Distribution and Submission of Results

Each participant downloaded the CEA MWCNT Prioritization Tool from the CEA Nanocarbon Web site (https://ceananocarbon.rti.org/). After using the Tool to complete a case study prioritization exercise, participants e-mailed their completed versions of the Tool to RTI (CEANanocarbon@rti.org).

K.4 Reporting and Next Steps

After the case study prioritization exercise was complete, the responses of the expert stakeholders engaged in the exercise (i.e., same application of the CEA Web Interface) were summarized. The aggregated responses from the entire group were shared with all participants. Each participant was also provided with a summary of his or her own responses and information on any next steps for the case study. After evaluating the collective opinions of the group, participants repeated the prioritization exercise, assisted in developing actionable research questions, and a subset of participants attended a face-to-face, structured collective judgment workshop to finalize and elaborate on research priorities.

K.5 CEA Web Interface

The CEA MWCNT Prioritization Tool provided a successful prototype for implementing the CEA Process. The Tool has since evolved into a Web-enabled tool known as the CEA Web Interface, located within the U.S. Environmental Protection Agency's (EPA's) Health & Environment Research Online (HERO) Web site (https://hero.epa.gov/cea). Participants can access this Web site only after logging in with a valid HERO user account. Information about the CEA Process is provided on the home page, along with links to the available case studies in ongoing or previous applications of the CEA approach.

The CEA Web Interface was designed to guide users through the steps that support the prioritization process. The Interface represents an effort to continue refining the CEA approach by facilitating remote stakeholder engagement in an intuitive Web interface that is capable of efficiently capturing data from multiple stakeholders in different locations.

Product Life Cycle

Element/RRF Pairs	Importance to Assessing Risk	Confidence in Data Availability & Utility for Assessing Risk	Why?
Raw Materials			
Volume			
Release Rate			
Material Synthesis			
Volume			
Release Rate			
Material Processing			
Volume			
Release Rate			
Product Manufacturing			
Volume			
Release Rate			
Product Storage, Transport			
Volume			
Release Rate			
Use			
Volume			
Release Rate			
Disposal/Recycling			
Volume			
Release Rate			

Figure K-1. Rating process screen 1: Product Life Cycle

Environmental Transport, Transformation & Fate

Element/RRF Pairs	Importance to Assessing Risk	Confidence in Data Availability & Utility for Assessing Risk	Why?
Air			
Mobility			
Persistence			
Bioavailability			
Surface Water			
Mobility			
Persistence			
Bioavailability			
Groundwater			
Mobility			
Persistence			
Bioavailability			
Wastewater			
Mobility			
Persistence			
Bioavailability			
Sediment			
Mobility			
Persistence			
Bioavailability			
Soil			
Mobility			
Persistence			
Bioavailability			
Biota			
Bioaccumulation			

Figure K-2. Rating process screen 2: Environmental Transport, Transformation & Fate

Exposure Route

Element/RRF Pairs	Importance to Assessing Risk	Confidence in Data Availability & Utility for Assessing Risk	Why?
Human: Occupational			
Ingestion			
Inhalation			
Dermal			
Human: Consumer			
Ingestion			
Inhalation			
Dermal			
Human: General Population			
Ingestion			
Inhalation			
Dermal			
Aquatic Biota			
Ingestion			
Inhalation			
Direct Contact			
Terrestrial Biota			
Ingestion			
Inhalation			
Direct Contact			
Abiotic			
Direct Contact			

Figure K-3. Rating process screen 3: Exposure Route

Dose (Kinetics)

Element/RRF Pairs	Importance to Assessing Risk	Confidence in Data Availability & Utility for Assessing Risk	Why?
Human			
Absorption			
Distribution			
Metabolism			
Excretion			
Aquatic Biota			
Absorption			
Distribution			
Metabolism			
Excretion			
Terrestrial Biota			
Absorption			
Distribution			
Metabolism			
Excretion			
Abiotic			
Absorption			

Figure K-4. Rating process screen 4: Dose (Kinetics)

Impacts

Element/RRF Pairs	Importance to Assessing Risk	Confidence in Data Availability & Utility for Assessing Risk	Why?
Human			
Cancer			
Non-cancer			
Reproductive/ Developmental			
Aquatic Biota			
Survival			
Developmental			
Reproductive			
Other Sublethal Endpoints			
Terrestrial Biota			
Survival			
Developmental			
Reproductive			
Other Sublethal Endpoints			
Other			
Economic			
Societal			
Environmental Resources			

Figure K-5. Rating process screen 5: Impacts

Appendix L
Workshop Presentation Slides

This Appendix contains all presentation slides from the face-to-face workshop conducted October 29–31, 2012 at U.S. EPA-RTP.

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes:

WELCOME

29 October 2012

Introductions

- RTI Project Manager – Khara Grieger
- RTI Support Staff
  - Kristin Smith, workshop coordinator
  - Tim Albrecht, workshop support
  - Steve Beaulieu, Director, Center for Health & Environmental Modeling and senior technical advisor to project
- CEA MWCNT Workshop Facilitator
  - Christine Hendren, Executive Director, Center for the Environmental Implications of NanoTechnology (CEINT)

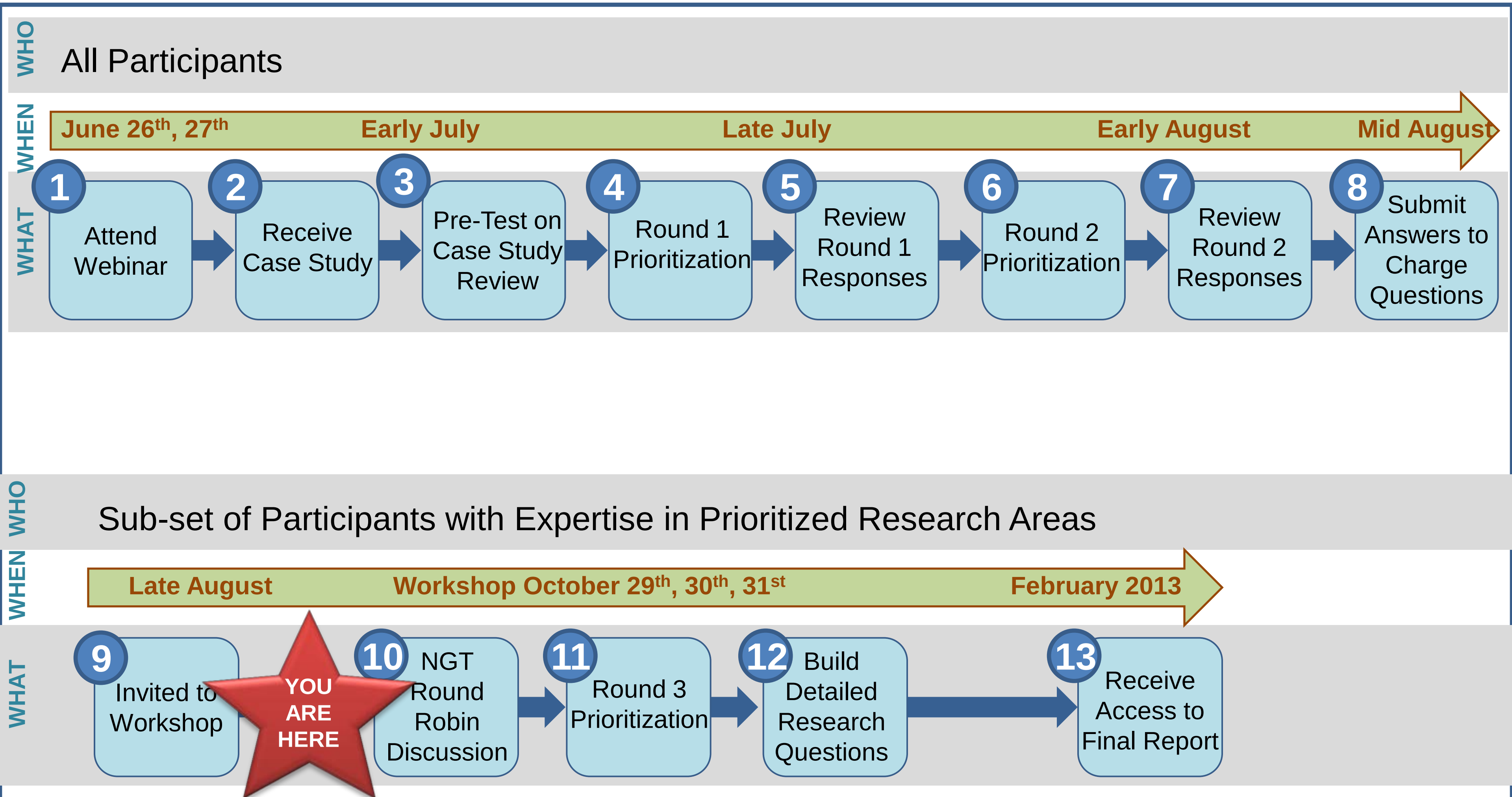
CEINT
Center for the Environmental Implications of NanoTechnology

www.ceint.duke.edu

CEA MWCNT Workshop Process

- You've heard
  - CEA applied to address emerging issues
  - CEA as applied to the MWCNT case study
  - How this efforts builds on previous case study processes
- You've participated
  - Reviewing the MWCNT case study
  - Two rounds of CEA prioritization
- Now....

CEA MWCNT Workshop Process



Moving Beyond Gap Analysis

- Increasing calls for focus on the RIGHT research
- Time to harness the research we have invested in over the past decade and move toward action

Calls for Linkages Between Research, Risk Assessment & Risk Management


EUROPEAN PARLIAMENT

Science and Technology Options Assessment

STOA

STOA

NanoSafety -
Risk Governance of Manufactured Nanoparticles

FINAL REPORT

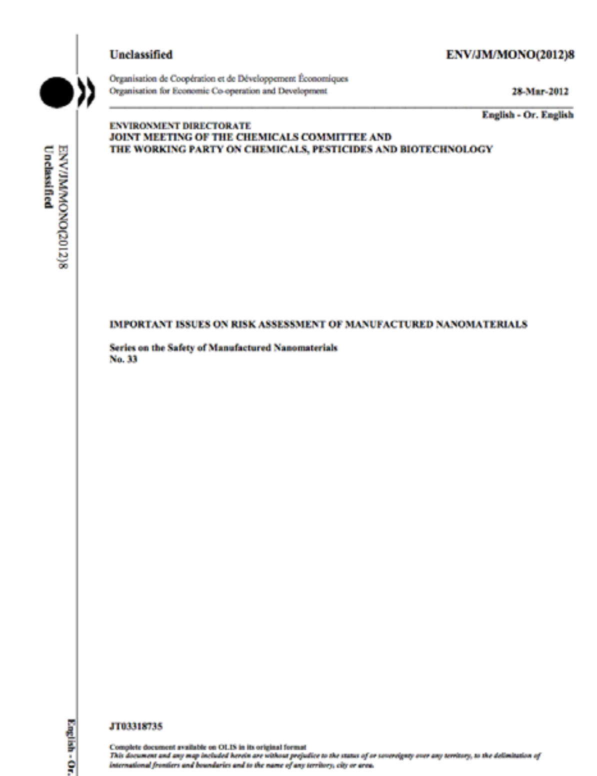
(IP/A/STOA/FWC/2008-096/LOT5/C1/SC3)

PE 482.685

- European Parliament Science and Technology Options Assessment (STOA) Report: NanoSafety – Risk Governance of Manufactured Nanoparticles, 2012
- Major conclusion: limitations of risk assessment research for supporting regulatory strategies

Research should support the discovery of knowledge that could feasibly inform choices between risk management options

Calls for Linkages Between Research, Risk Assessment & Risk Management


Unclassified ENV/JM/MONO(2012)8

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development 28-Mar-2012

English - Or. English

ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

IMPORTANT ISSUES ON RISK ASSESSMENT OF MANUFACTURED NANOMATERIALS

Series on the Safety of Manufactured Nanomaterials
No. 33

JT03318735

Complete document available on OLIS in its original format
This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

ENV/JM/MONO(2012)8
Unclassified

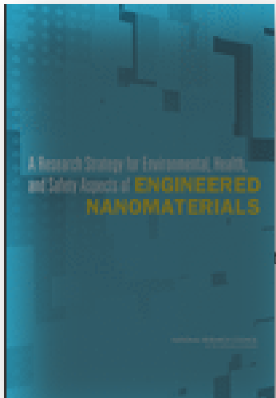
English - Or. E

- OECD Environment, Health and Safety Publications Series on the Safety of Manufactured Nanomaterials No. 33: Important Issues on Risk Assessment of Manufactured Nanomaterials, 2012

- Notes the role of risk management options in shaping the direction of risk assessments

“Given that nanomaterial risk assessment may have limited relevant empirical data, introducing risk management measures as part of the problem formulation stage provides opportunity to limit *[intelligently direct]* the scope of the risk assessment.”

Calls for Linkages Between Research, Risk Assessment & Risk Management



5

riorities and Resource Needs

OVERVIEW

Chapter 2 developed a conceptual framework (Figure 2-1) for considering environmental, health, and safety (EHS) risks related to nanomaterials and to help prioritize activities within a strategic research plan. Three overarching principles were developed to guide the development of strategic research and to identify ENMs requiring particular attention; emergent risk, plausibility and severity. In addition, specific criteria were established as a basis for assigning research priorities:

- Research that advances knowledge of both exposure and hazard wherever possible.
- Research that leads to the production of risk information needed to inform decision-making on nanomaterials in the market place.
- Research efforts to address short-term needs that serve as a foundation for moving beyond case-by-case evaluations of nanomaterials and allow longer-term forecasting of risks posed by newer materials expected to enter commerce.
- Research that promotes the development of critical supporting tools, such as measurement methods, limitations of which hinder the conduct of research in processes that control hazards and exposure.
- Research on ecosystem-level effects that addresses exposure or hazard scenarios that are underrepresented in the current portfolio of nanotechnology-related EHS research; for example, impacts on ecosystem processes and on organisms representing different phyla and environments.

Chapter 3 reviewed what is known about the EHS aspects of nanomaterials in the context of the conceptual framework and identified critical research questions that remain unanswered, focusing on processes most likely to affect exposure and hazards related to engineered nanomaterials (ENMs) (circle in Figure 2-1). Chapter 4 addressed tools needed for characterizing how the proper-

143

- National Research Council Report: A Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials, 2012
- "Research Priorities and Resource Needs: Research that leads to the production of risk information needed to inform decision-making on nanomaterials in the market place"

CEA MWCNT Prioritization Workshop: Objectives

1. To build out detailed, actionable research questions around the prioritized areas of the CEA framework, *in the context of the assessments and subsequent risk management decisions this research would support*.

2. To generate feedback that will help build on and improve the CEA prioritization process for use in addressing emerging technologies characterized by uncertainty.

CEA MWCNT Prioritization Workshop

- This is an opportunity to add significant value by:
  - Laying the groundwork for identifying and ultimately informing risk management decisions that need to be made regarding MWCNTs.
  - Rising to the timely calls for focused research that addresses specific information needs to enable assessment and management of risks posed by engineered nanomaterials.

Scope Clarification

Question: In considering research priorities for MWCNT, do we always intend to focus on 'MWCNT as used in flame retardant textile coating'?

Yes. For this whole workshop we are specifically considering research that would enable us to assess the impacts of MWCNT as used in flame retardant coatings for textiles.

- In all cases that you can specifically consider this application, do so. Keep in mind, the CEA framework includes the entire life cycle process of the MWCNT as produced, used in, and disposed after this application.
- In any case where there is not be relevant data/information available to apply from this particular use, then refer to knowledge about MWCNTs in general.
- If there are not even specific data surrounding MWCNT, then refer to other background knowledge including information about nanomaterials in general.

Scope Clarification

- In CEA we think that identifying potential risks (and related research questions) is facilitated by thinking about particular applications but a potential risk (and related research questions) could apply to multiple applications

- E.g., research on potential release of MWCNT from textile coatings may inform understanding of potential release of MWCNT from electronic coatings

Agenda

DAY 1

- Nominal Group Technique round robin discussion
- Round 3 of CEA MWCNT Prioritization
- EPA demonstration of web-based CEA Prioritization tool

DAY 2

- Review Round 3 Results
- Process feedback
- Breakout group activities focused around high priority E-RRF pairs

DAY 3

- Breakout group reports

Ground Rules

- Arrive and start on time
- Be present and engaged – no technology please!
- One person speaks at a time
- All ideas and opinions are respected
- Stay focused on the workshop objectives

Administrivia

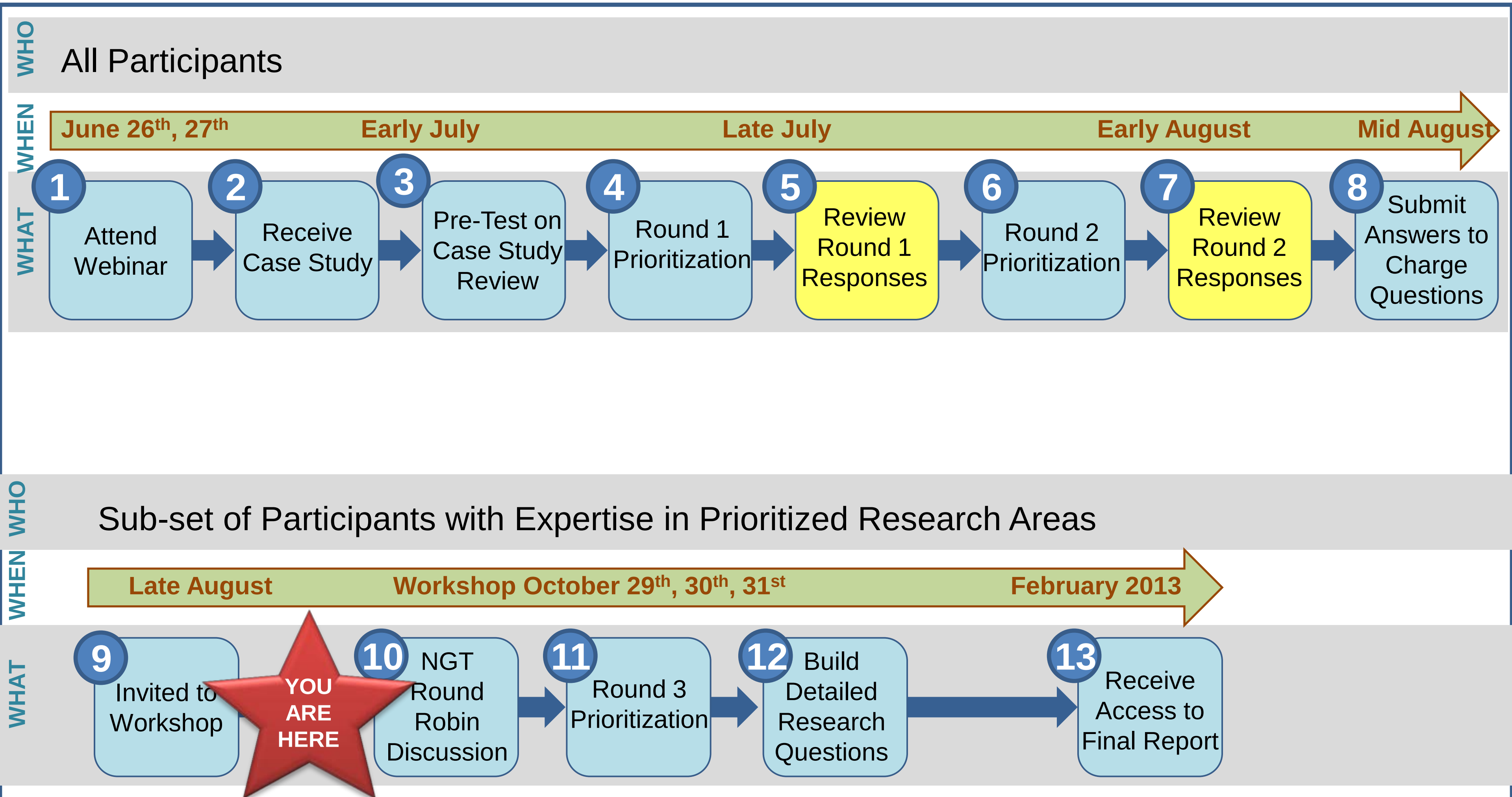
- Bathroom locations
- Coffee / refreshments are available at the café and at the convenience store at the top of the stairs behind the security desk
- Cell phone access is best in the upstairs lobby or potentially outside – if you exit the front door you will be able to enter with your conference badge
- RTI Staff available for logistics questions
  - Khara Grieger
  - Kristin Smith
- Honoraria checks will be mailed immediately after the workshop concludes, including the honorarium, the per diem for your food allowance, and the allotted taxi funds

turning knowledge into practice

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes:
Review of Prioritization Scores to Date

29 October 2012

CEA MWCNT Prioritization Tool: Analytical Results

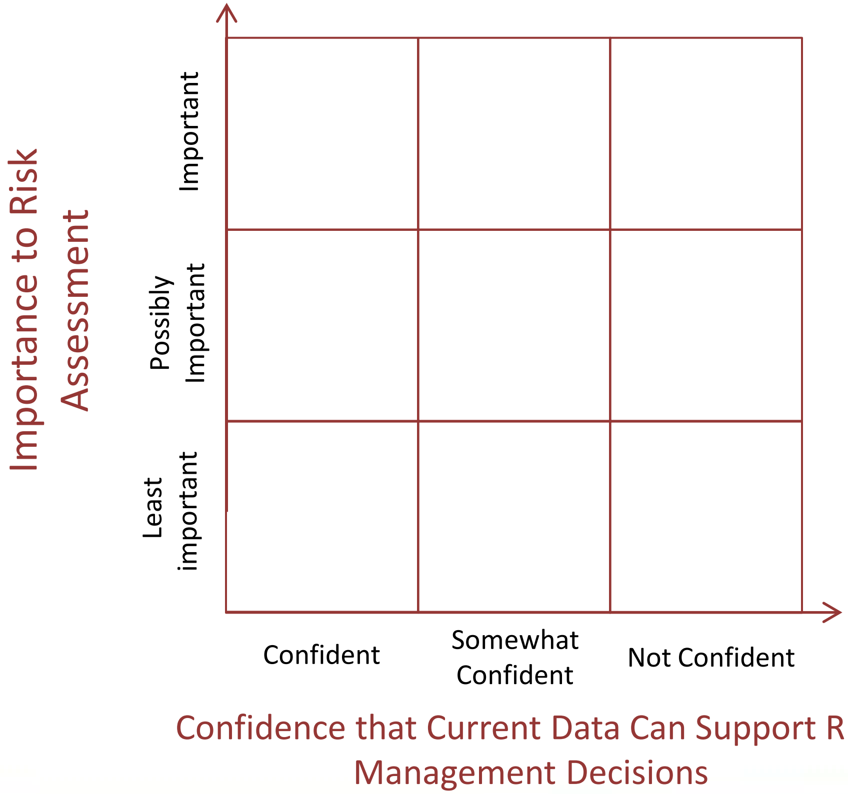


CEA MWCNT Prioritization Tool: Analytical Results

- After each round of the CEA Prioritization Process, several analytical reports were distributed to each of you for individual review and consideration.
- The purpose of these reports was to summarize the judgments of all participants.
- By providing you access to the expert opinions of the broad spectrum of your peers, this process was intended to foster consideration and integration of other viewpoints.

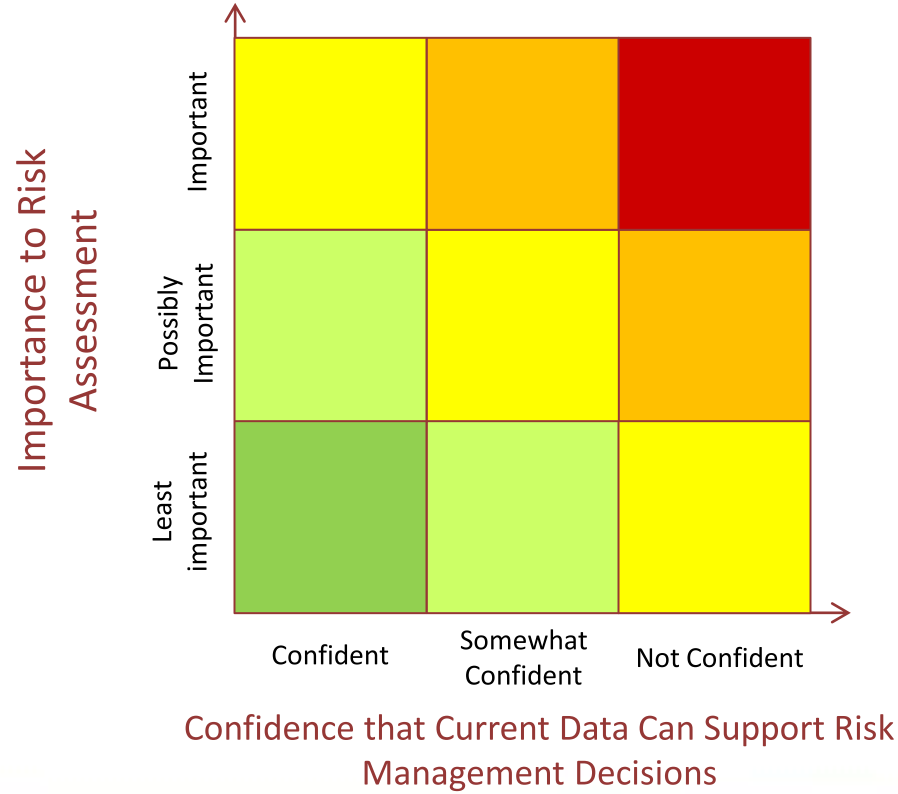
CEA MWCNT Prioritization Tool Output

- The output from the MWCNT Prioritization exercise is summarized in a matrix to capture expert opinion.



CEA MWCNT Prioritization Tool Output

- Research areas falling into red or orange boxes of the CEA Prioritization Matrix will be elevated for development of research questions during the Final Workshop (CEA Prioritization Round 3).



Round 1 Results Overview

Round 1

Results of Round 1: Importance/Confidence Matrix

*I: %; C: % represents the percentage of total respondents who chose the cell's Importance and Confidence responses, respectively for the listed Element-Risk Relevance Factor.

	Confident	Somewhat Confident	Not Confident
Important	• Product Life Cycle-Material Synthesis-Volume, I: 58%; C: 29% • Product Life Cycle-Material Processing-Volume, I: 45%; C: 23% • Product Life Cycle-Disposal/Recycling-Volume, I: 55%; C: 23%	• Product Life Cycle-Material Processing-Release Rate, I: 35%; C: 23% • Exposure Route-Human: Occupational-Inhalation, I: 97 C: 39% • Impacts-Aquatic Biota-Survival, I: 35%; C: 19%	• Product Life Cycle-Material Synthesis-Release Rate, I: 55%; C: 32% • Product Life Cycle-Product Manufacturing-Volume, I: 65%; C: 32% • Product Life Cycle-Product Manufacturing-Release Rate, I: 68%; C: 35% • Product Life Cycle-Use-Volume, I: 55%; C: 29% • Product Life Cycle-Use-Release Rate, I: 58%; C: 42% • Product Life Cycle-Disposal/Recycling-Release Rate, I: 55%; C: 35% • Env. TT&F-Air-Mobility, I: 77%; C: 55% • Env. TT&F-Air-Persistence, I: 55%; C: 48% • Env. TT&F-Air-Bioavailability, I: 58%; C: 61% • Env. TT&F-Surface Water-Mobility, I: 39%; C: 19% • Env. TT&F-Surface Water-Persistence, I: 29%; C: 19% • Env. TT&F-Surface Water-Bioavailability, I: 32%; C: 26% • Env. TT&F-Wastewater-Mobility, I: 55%; C: 32% • Env. TT&F-Wastewater-Persistence, I: 48%; C: 32% • Env. TT&F-Wastewater-Bioavailability, I: 35%; C: 39% • Env. TT&F-Soil-Mobility, I: 23%; C: 26% • Env. TT&F-Soil-Persistence, I: 39%; C: 23% • Env. TT&F-Soil-Bioavailability, I: 39%; C: 29% • Env. TT&F-Biota-Bioaccumulation, I: 42%; C: 26% • Exposure Route-Human: Consumer-Ingestion, I: 35%; C: 39% • Exposure Route-Human: Consumer-Inhalation, I: 52%; C: 35% • Dose (Kinetics)-Human-Absorption, I: 77%; C: 61% • Dose (Kinetics)-Human-Distribution, I: 71%; C: 61% • Dose (Kinetics)-Human-Metabolism, I: 48%; C: 68% • Dose (Kinetics)-Human-Excretion, I: 65%; C: 65% • Dose (Kinetics)-Aquatic Biota-Absorption, I: 39%; C: 23% • Dose (Kinetics)-Aquatic Biota-Distribution, I: 39%; C: 32% • Dose (Kinetics)-Aquatic Biota-Metabolism, I: 23%; C: 35% • Dose (Kinetics)-Aquatic Biota-Excretion, I: 32%; C: 32% • Impacts-Human-Cancer, I: 74%; C: 52% • Impacts-Human-Non-cancer, I: 68%; C: 45% • Impacts-Aquatic Biota-Developmental, I: 29%; C: 32% • Impacts-Aquatic Biota-Reproductive, I: 29%; C: 32% • Impacts-Aquatic Biota-Other Sublethal Endpoints, I: 16%; C: 32%
Possibly Important			• Exposure Route-Human: Occupational-Dermal, I: 39%; C: 45% • Exposure Route-Human: Consumer-Dermal, I: 26%; C: 39% • Impacts-Human-Reproductive/ Developmental, I: 48%; C: 68%
Least Important			

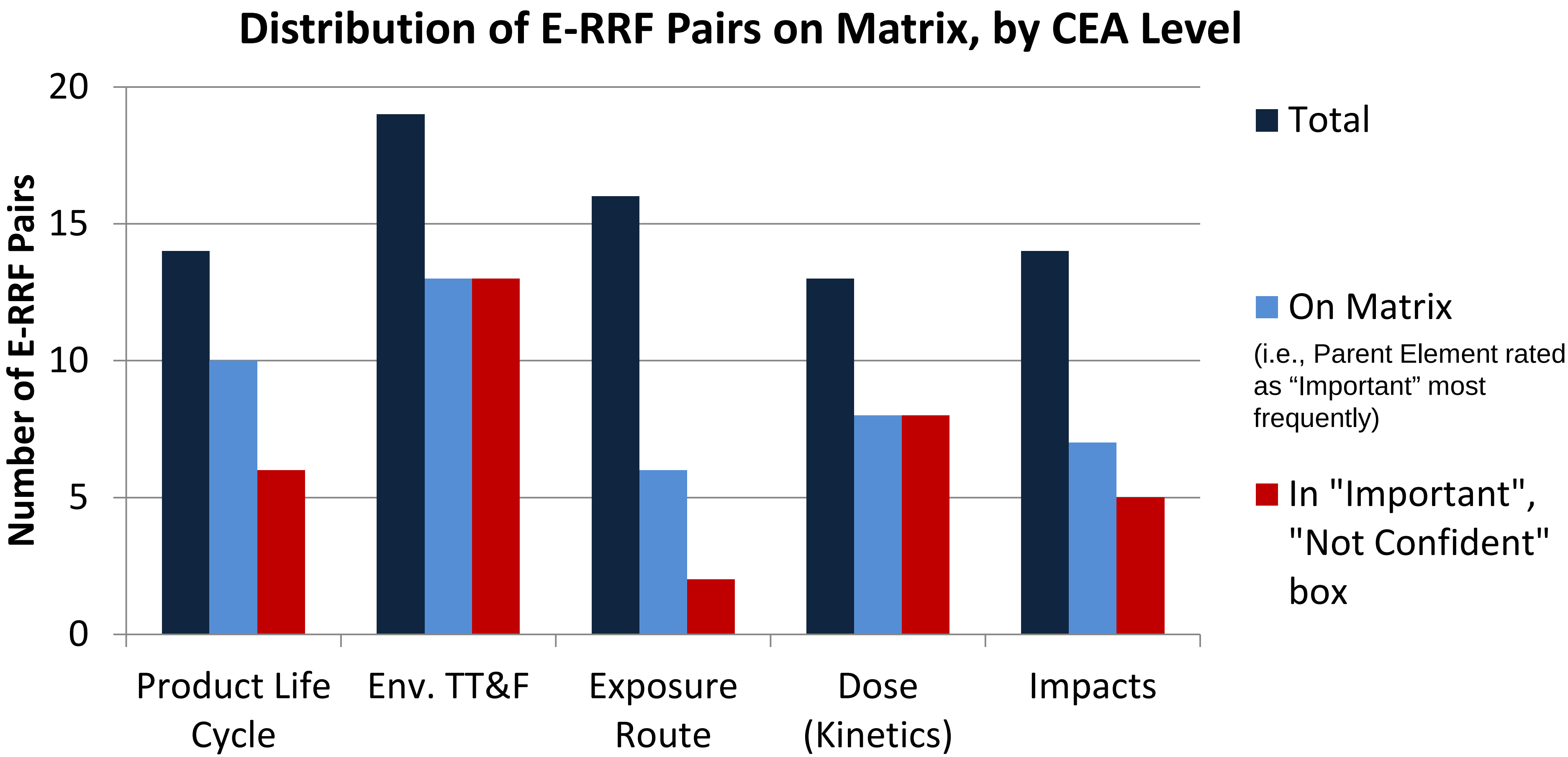
- A large majority of E-RRF pairs on the Matrix were grouped into the highest priority (red) bin
- "Important", "Not Confident"
    - 34 / 43 E-RRF pairs
    - 79%

Results of Round 1: Importance/Confidence Matrix

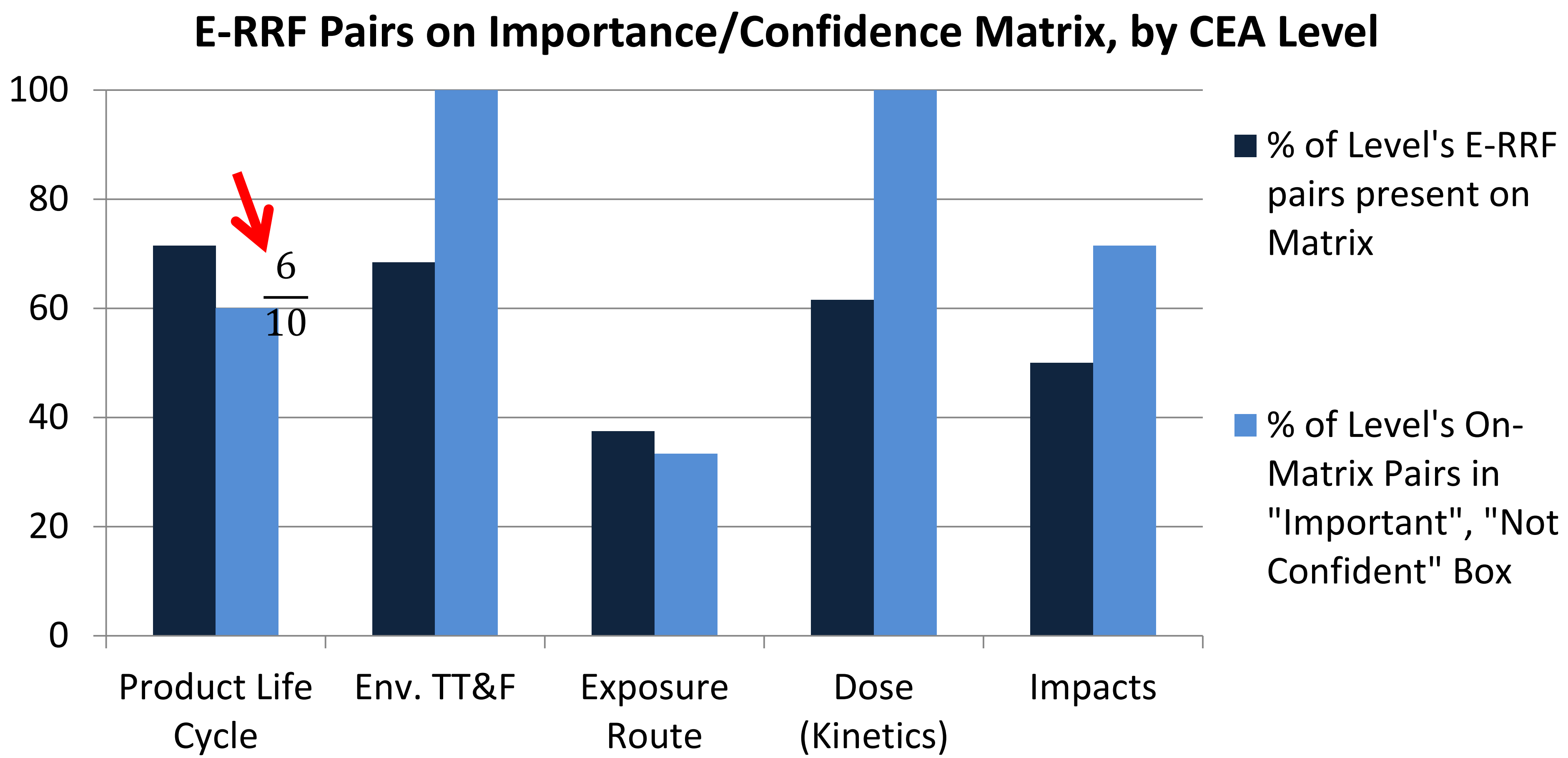
- Product Life Cycle-Material Synthesis-Release Rate, I: 55%; C: 32%
- Product Life Cycle-Product Manufacturing-Volume, I: 65%; C: 32%
- Product Life Cycle-Product Manufacturing-Release Rate, I: 68%; C: 35%
- Product Life Cycle-Use-Volume, I: 55%; C: 29%
- Product Life Cycle-Use-Release Rate, I: 58%; C: 42%
- Product Life Cycle-Disposal/Recycling-Release Rate, I: 55%; C: 35%
- Env. TT&F-Air-Mobility, I: 77%; C: 55%
- Env. TT&F-Air-Persistence, I: 55%; C: 48%
- Env. TT&F-Air-Bioavailability, I: 58%; C: 61%
- Env. TT&F-Surface Water-Mobility, I: 39%; C: 19%
- Env. TT&F-Surface Water-Persistence, I: 29%; C: 19%
- Env. TT&F-Surface Water-Bioavailability, I: 32%; C: 26%
- Env. TT&F-Wastewater-Mobility, I: 55%; C: 32%
- Env. TT&F-Wastewater-Persistence, I: 48%; C: 32%
- Env. TT&F-Wastewater-Bioavailability, I: 35%; C: 39%
- Env. TT&F-Soil-Mobility, I: 23%; C: 26%
- Env. TT&F-Soil-Persistence, I: 39%; C: 23%
- Env. TT&F-Soil-Bioavailability, I: 39%; C: 29%
- Env. TT&F-Biota-Bioaccumulation, I: 42%; C: 26%
- Exposure Route-Human: Consumer-Ingestion, I: 35%; C: 39%
- Exposure Route-Human: Consumer-Inhalation, I: 52%; C: 35%
- Dose (Kinetics)-Human-Absorption, I: 77%; C: 61%
- Dose (Kinetics)-Human-Distribution, I: 71%; C: 61%
- Dose (Kinetics)-Human-Metabolism, I: 48%; C: 68%
- Dose (Kinetics)-Human-Excretion, I: 65%; C: 65%
- Dose (Kinetics)-Aquatic Biota-Absorption, I: 39%; C: 23%
- Dose (Kinetics)-Aquatic Biota-Distribution, I: 39%; C: 32%
- Dose (Kinetics)-Aquatic Biota-Metabolism, I: 23%; C: 35%
- Dose (Kinetics)-Aquatic Biota-Excretion, I: 32%; C: 32%
- Impacts-Human-Cancer, I: 74%; C: 52%
- Impacts-Human-Non-cancer, I: 68%; C: 45%
- Impacts-Aquatic Biota-Developmental, I: 29%; C: 32%
- Impacts-Aquatic Biota-Reproductive, I: 29%; C: 32%
- Impacts-Aquatic Biota-Other Sublethal Endpoints, I: 16%; C: 32%

- All 5 CEA Levels represented in highest-priority box alone

Results of Round 1: Importance/Confidence Matrix

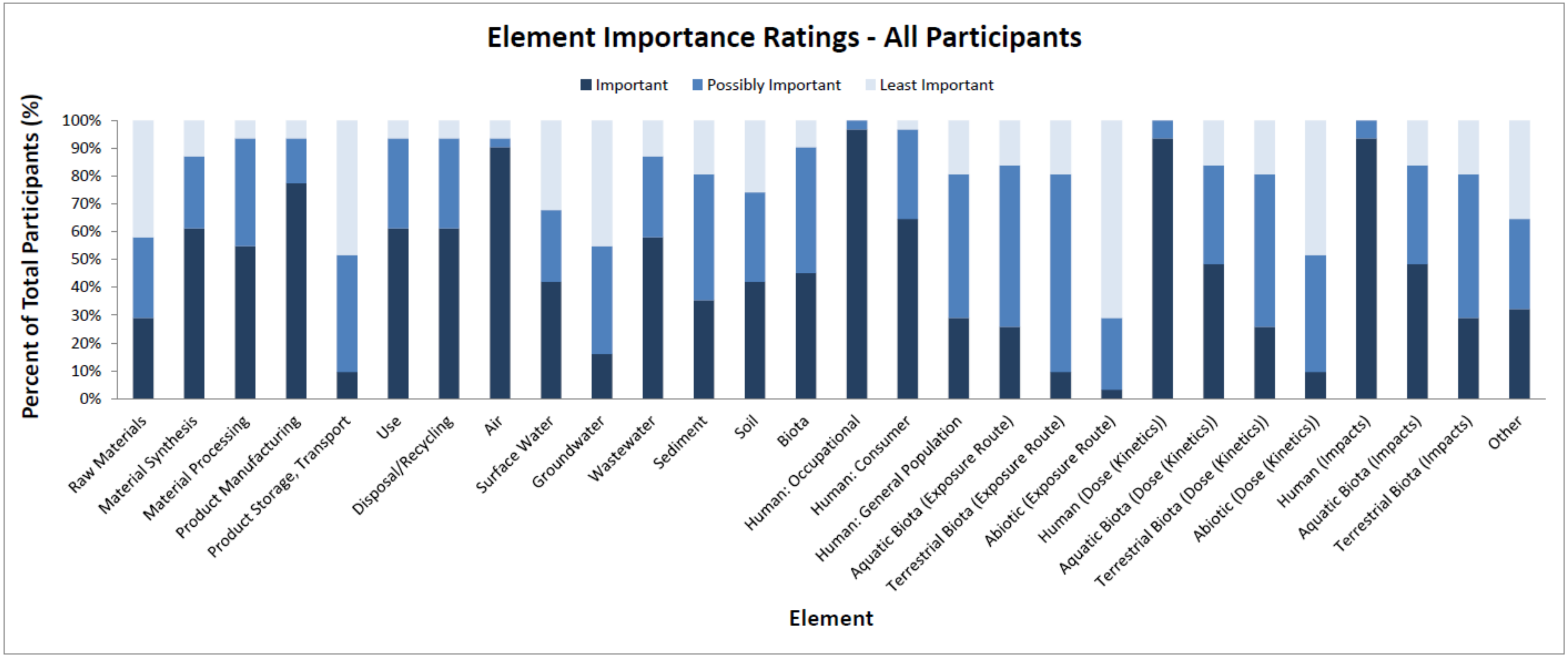


Results of Round 1: Importance/Confidence Matrix

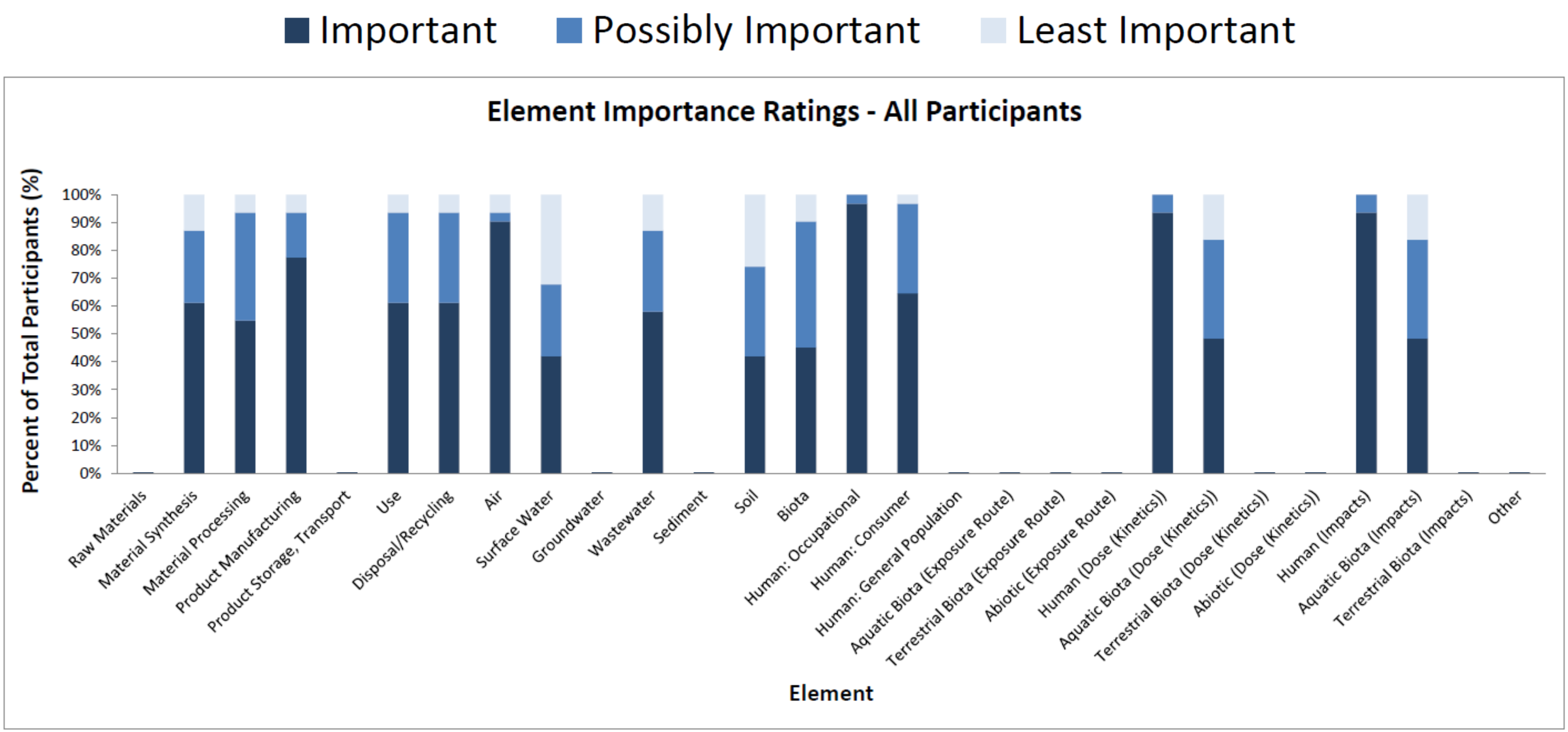


Results of Round 1: Element Importance Ratings

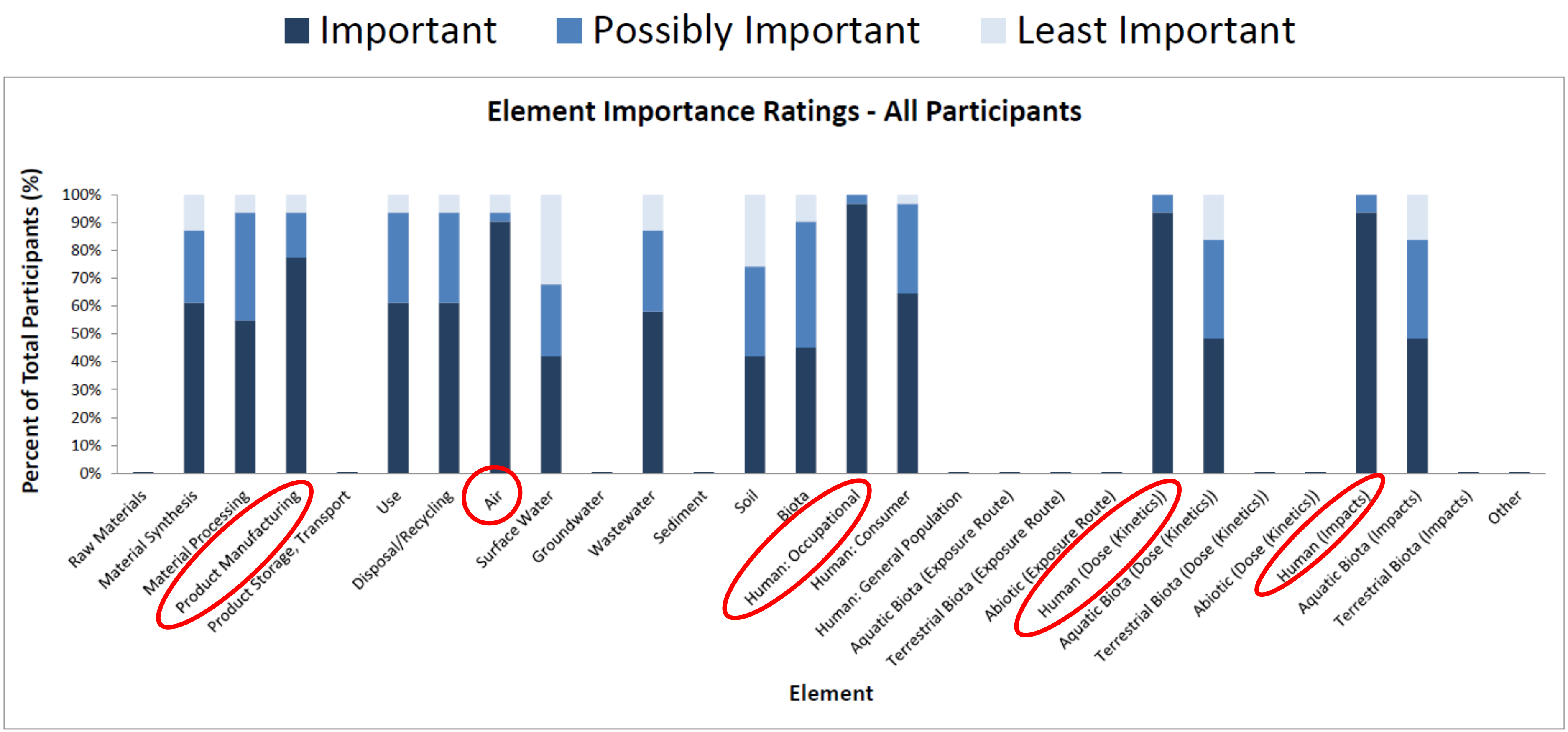
Important Possibly Important Least Important



Results of Round 1: Element Importance Ratings, On-Matrix



Results of Round 1: Element Importance Ratings, Top 5



Round 1 Results Overview

Round 2

Results of Round 2: Importance/Confidence Matrix

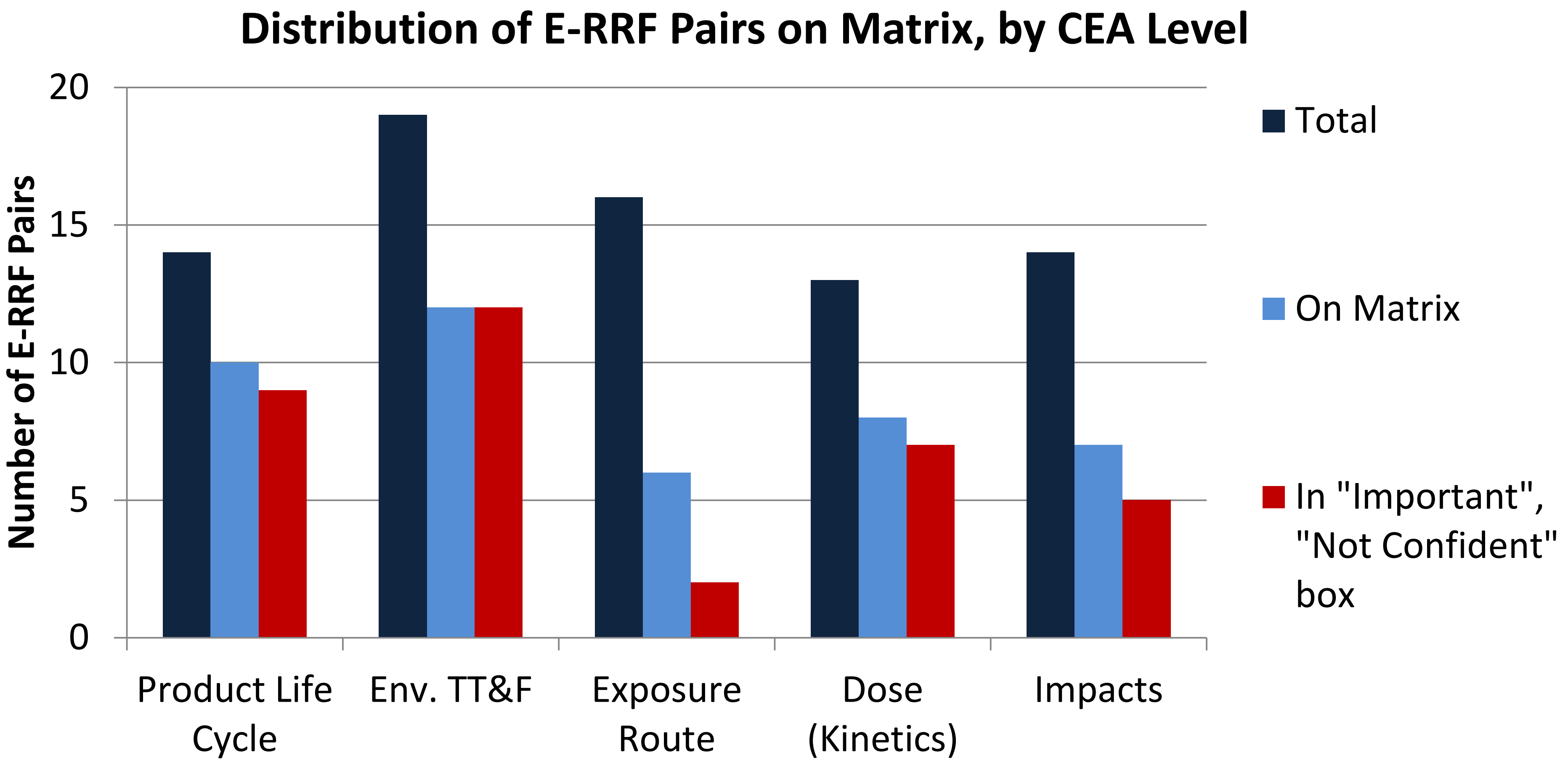
- A large majority of E-RRF pairs (slightly larger than Round 1) on the Matrix were grouped into the highest priority (red) bin
- “Important”, “Not Confident”
  - 35 / 42 E-RRF pairs
  - 83%

Results of Round 2: Importance/Confidence Matrix

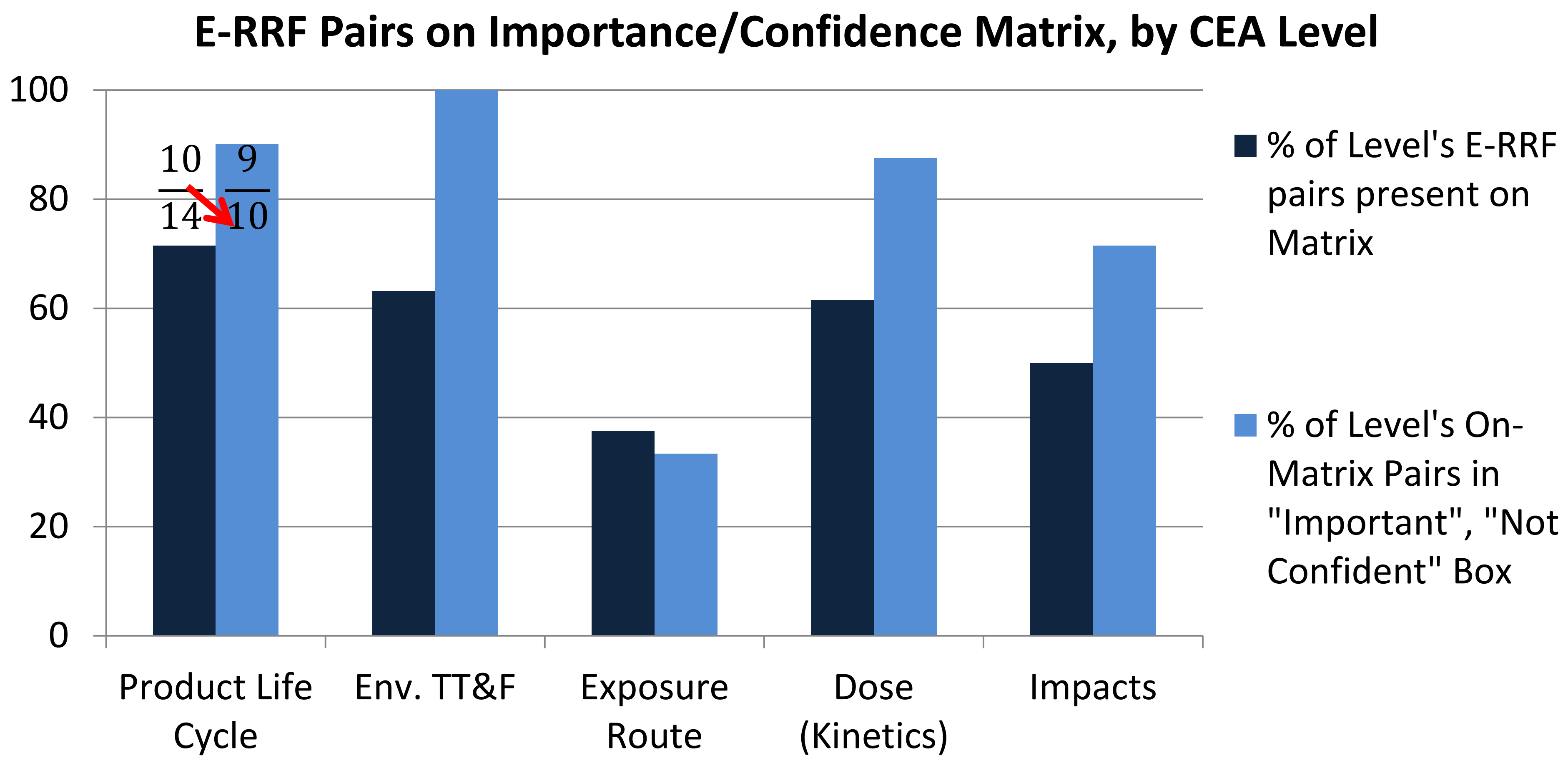
- Product Life Cycle-Material Synthesis-Volume, I: 57%; C: 25%
- Product Life Cycle-Material Synthesis-Release Rate, I: 61%; C: 36%
- Product Life Cycle-Material Processing-Release Rate, I: 29%; C: 25%
- Product Life Cycle-Product Manufacturing-Volume, I: 71%; C: 36%
- Product Life Cycle-Product Manufacturing-Release Rate, I: 68%; C: 39%
- Product Life Cycle-Use-Volume, I: 61%; C: 36%
- Product Life Cycle-Use-Release Rate, I: 64%; C: 57%
- Product Life Cycle-Disposal/Recycling-Volume, I: 46%; C: 25%
- Product Life Cycle-Disposal/Recycling-Release Rate, I: 46%; C: 36%
- Env. TT&F-Air-Mobility, I: 82%; C: 61%
- Env. TT&F-Air-Persistence, I: 54%; C: 57%
- Env. TT&F-Air-Bioavailability, I: 64%; C: 64%
- Env. TT&F-Wastewater-Mobility, I: 64%; C: 36%
- Env. TT&F-Wastewater-Persistence, I: 61%; C: 36%
- Env. TT&F-Wastewater-Bioavailability, I: 39%; C: 50%
- Env. TT&F-Sediment-Mobility, I: 18%; C: 21%
- Env. TT&F-Sediment-Persistence, I: 36%; C: 21%
- Env. TT&F-Sediment-Bioavailability, I: 39%; C: 29%
- Env. TT&F-Soil-Mobility, I: 14%; C: 21%
- Env. TT&F-Soil-Persistence, I: 32%; C: 18%
- Env. TT&F-Soil-Bioavailability, I: 36%; C: 25%
- Exposure Route-Human: Consumer-Ingestion, I: 39%; C: 43%
- Exposure Route-Human: Consumer-Inhalation, I: 46%; C: 36%
- Dose (Kinetics)-Human-Absorption, I: 79%; C: 64%
- Dose (Kinetics)-Human-Distribution, I: 71%; C: 64%
- Dose (Kinetics)-Human-Metabolism, I: 43%; C: 68%
- Dose (Kinetics)-Human-Excretion, I: 57%; C: 64%
- Dose (Kinetics)-Aquatic Biota-Absorption, I: 43%; C: 21%
- Dose (Kinetics)-Aquatic Biota-Distribution, I: 43%; C: 32%
- Dose (Kinetics)-Aquatic Biota-Excretion, I: 32%; C: 29%
- Impacts-Human-Cancer, I: 82%; C: 50%
- Impacts-Human-Non-cancer, I: 64%; C: 39%
- Impacts-Aquatic Biota-Developmental, I: 36%; C: 32%
- Impacts-Aquatic Biota-Reproductive, I: 32%; C: 32%
- Impacts-Aquatic Biota-Other Sublethal Endpoints, I: 21%; C: 36%

- All 5 CEA Levels represented in highest-priority box alone

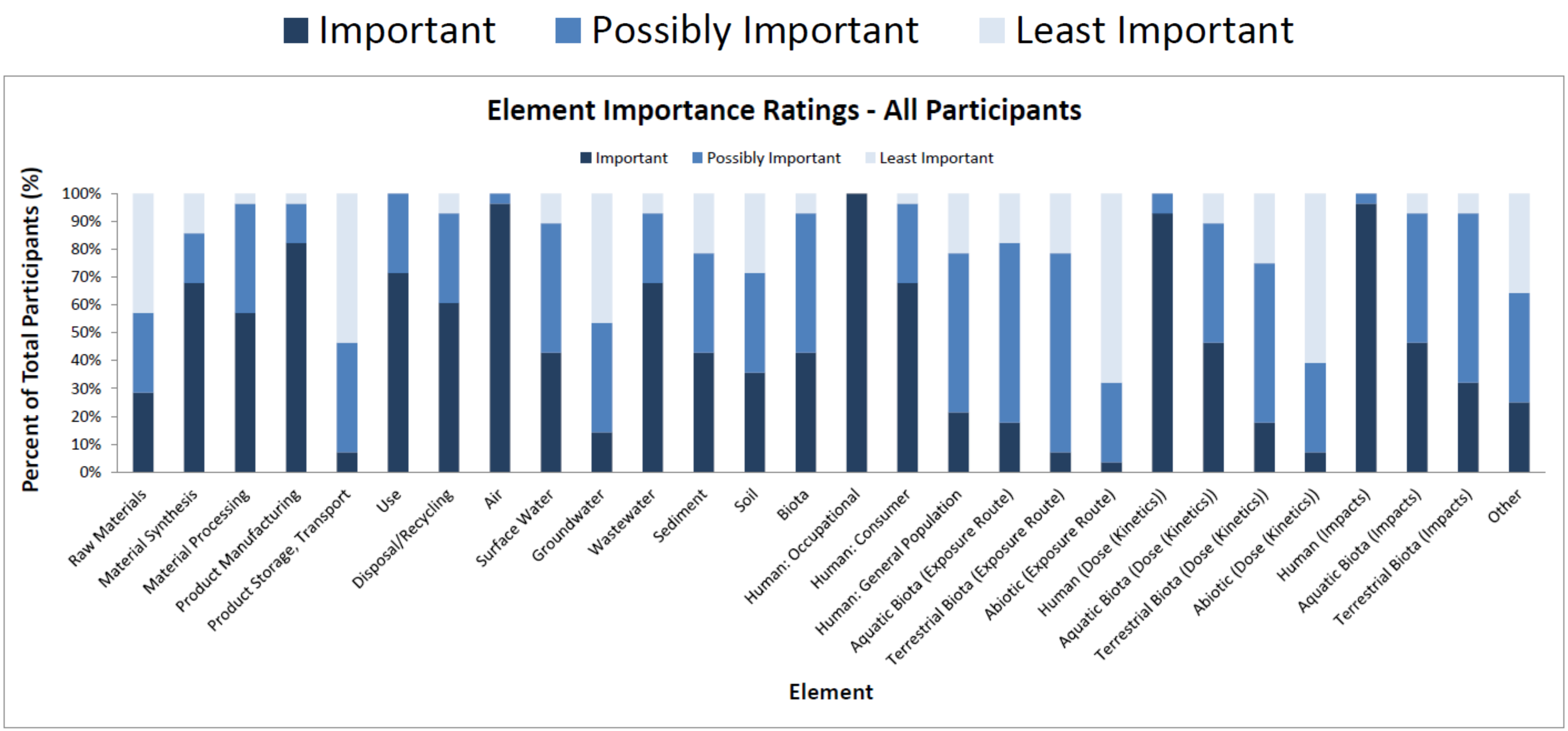
Results of Round 2: Importance/Confidence Matrix



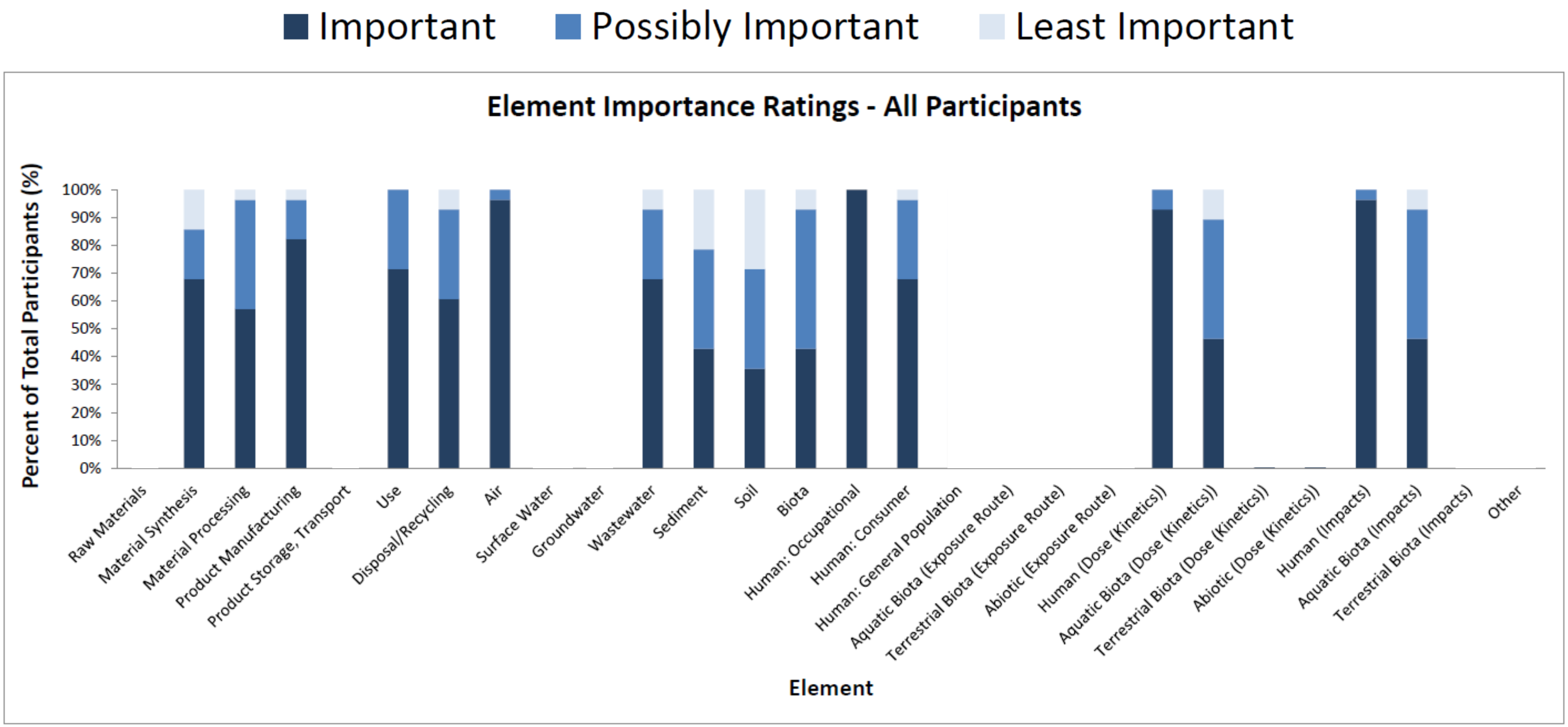
Results of Round 2: Importance/Confidence Matrix



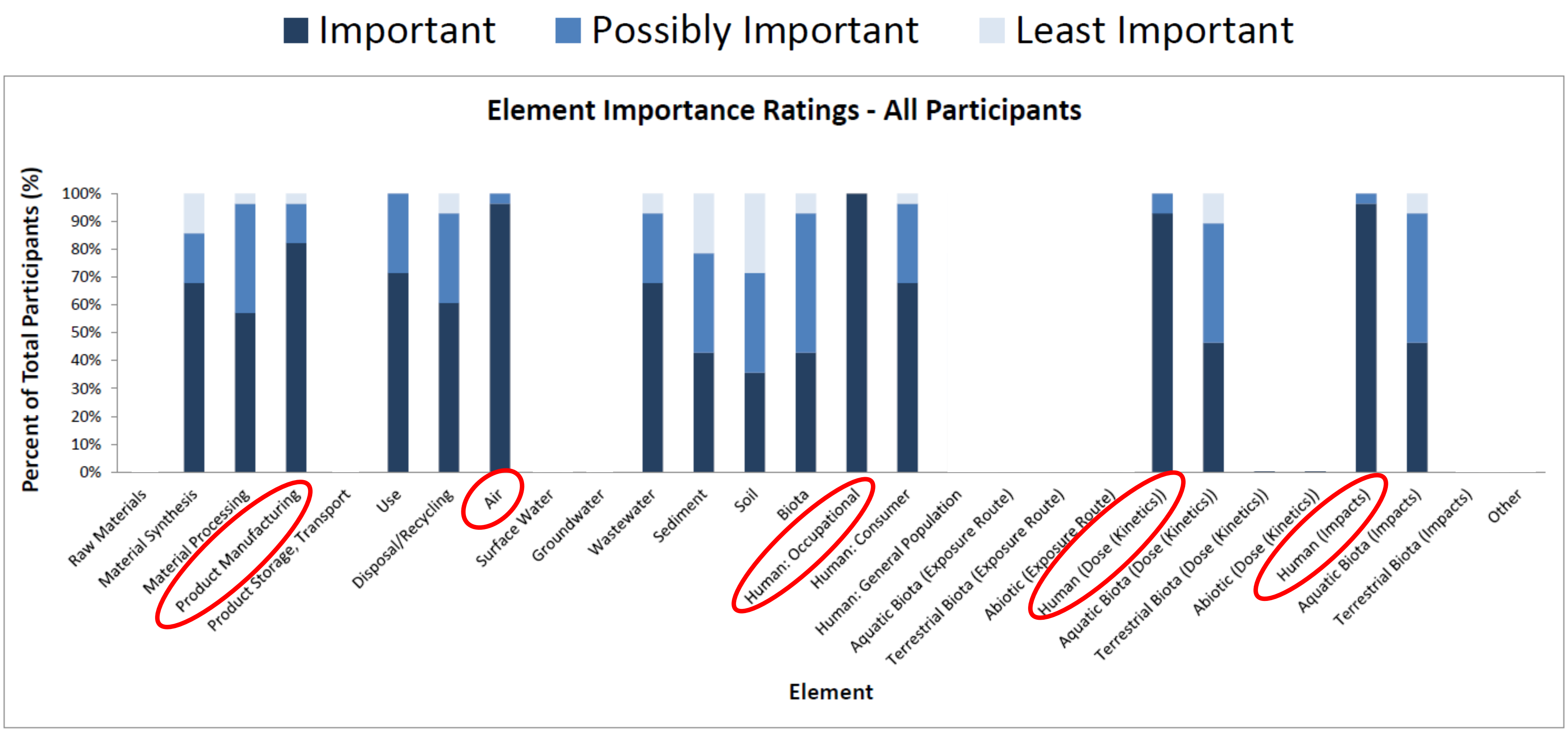
Results of Round 2: Element Importance Ratings



Results of Round 2: Element Importance Ratings, On-Matrix



Results of Round 2: Element Importance Ratings, Top 5



Changes from Round 1 to Round 2

CEA Level	Number of E-RRF Pairs	Number of E-RRF Pairs in "Important", "Not Confident" Bin			Percent of E-RRF Pairs in "Important", "Not Confident" Bin		
		Round 1	Round 2	**Change**	Round 1	Round 2	**Change**
Product Life Cycle	14	6	9	**+3**	43%	64%	**+21**
Environmental Transport, Transformation & Fate	19	13	12	**-1**	68%	63%	**-5**
Exposure Route	16	2	2	**0**	13%	13%	**0**
Dose (Kinetics)	13	8	7	**-1**	62%	54%	**-8**
Impacts	14	5	5	**0**	36%	36%	**0**

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Nominal Group Technique

October 29th 2012

Nominal Group Technique

Nominal Group Technique (NGT) is an organized process that helps facilitate discussion in a group setting and ensures that diverse perspectives are heard

Each individual is given an equal opportunity to offer his/her views about which choices should have the highest priority

↓

Multiple related choices can be consolidated and break-out groups will allow for expansion of details for the top choices

NGT Process for MWCNT CEA

Stage 1: Round Robin (~3 Rounds)

- Each workshop participant will be given 3 minutes to present his/her case for elevating an E-RRF pair to high priority for further attention in a breakout group
- No visual aids
- A participant can use his/her 3 minutes to support someone else's choice or offer up a new priority
- On your way to the podium, please place a post-it on the Detailed CEA Framework on the E-RRF pair you are addressing
  - ★ Use a star to advocate FOR the E-RRF
  - ☒ Use an X to indicate that you do NOT believe the E-RRF should be a priority
- Time is strictly enforced

NGT Process for MWCNT CEA

Stage 1: Round Robin

What to do with your 3 minutes

1) Briefly introduce yourself
2) State which E-RRF pair you think is most important to investigate and why?
3) If you agree/disagree with a previous participants' priority, state this along with your rationale
4) Be mindful of the 3 minute time limit

- When you are making your 3 minute "case", you are advocating for why people should rate the E-RRF as Important and why you believe there is not sufficient information to enable an assessment.
- You want to encourage the most # of people possible to rate this E-RRF in this way to ensure it receives detailed attention in the break-out groups.

NGT Process for MWCNT CEA

Stage 2: Prioritizing

- The output of Nominal Group Technique is usually a ranked list; in our case we will be utilizing the round robin to inform individual CEA Prioritization.
- Each workshop participant will perform a final ranking of E-RRF pairs based on the Round Robin presentations.
- Rankings will be entered into an Excel spreadsheet and individually collected via flash drives.
- Final rankings will be evaluated by staff and provided to the group on the following day.

NGT Process for MWCNT CEA

Stage 3: Elevation of Top E-RRFs to Break-out Groups

- The top 14-16 E-RRF pairs identified in the final round of voting will be distributed among 4-5 break-out groups based on participant expertise
- Break-out groups will follow a discussion template to detail specific research questions related to their specific E-RRF pairs
- A more detailed explanation of the break-out group process and discussion template will precede group discussions tomorrow

NGT Process for MWCNT CEA

Determining the "Top" E-RRFs

- As you know from the CEA MWCNT prioritization worksheet, this process was built on rating rather than directly ranking.
- The "Top" E-RRF pairs were determined by a relative rank of individual E-RRF pairs based on the Round 2 group ratings of prioritized areas.
  - The aggregated data from the boxes in the Round 2 matrix consisted of the E-RRF pair name, the % of participants who chose that box's importance rating, and the % of participants who chose that confidence rating.
  - To rank from most prioritized → least prioritized E-RRF pairs, the % of participants selecting a particular importance rating ($I_{E\text{-}RRF}$) was added to the % of participants selecting a particular confidence rating ($C_{E\text{-}RRF}$) within a specific color group from the matrix, such that the overall score $S_{E\text{-}RRF} = I_{E\text{-}RRF} + C_{E\text{-}RRF}$

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes:

Round 3 Prioritization

29 October 2012

CEA MWCNT Round 3 Prioritization

WHO: All Participants

WHEN: June 26th, 27th — Early July — Late July — Early August — Mid August

WHAT:

1. Attend Webinar
2. Receive Case Study
3. Pre-Test on Case Study Review
4. Round 1 Prioritization
5. Review Round 1 Responses
6. Round 2 Prioritization
7. Review Round 2 Responses
8. Submit Answers to Charge Questions

WHO: Sub-set of Participants with Expertise in Prioritized Research Areas

WHEN: Late August — Workshop October 29th, 30th, 31st — February 2013

WHAT:

9. Invited to Workshop
10. Rou… Rob… Discu…ion
11. Round 3 Prioritization
12. Build Detailed Research Questions
13. Receive Access to Final Report

YOU ARE HERE

CEA MWCNT Round 3 Prioritization

- Consider what you just learned through NGT
  - The flip chart notes from the session will be posted around the room where you are carrying out CEA MWCNT Round 3 Prioritization

- Utilize the material in your welcome folders and on the flash drives RTI is handing out right now, containing:
  - The CEA MWCNT Prioritization Tool
  - The Draft Case Study Document
  - Detailed CEA Diagram and Influential Factors List

CEA MWCNT Round 3 Prioritization

Carry out Round 3 Prioritization

- Enter responses for “why” as you see necessary, but due to time constraints this will be limited; this information will not be used to carry out the prioritization but will be available for help in the breakout groups

- Only select Influential Factors if/when they pertain directly to your reasons why; again, the primary goal of Round 3 Prioritization is to select the ultimate list of prioritized E-RRF pairs

United States Environmental Protection Agency

Comprehensive Environmental Assessment Web Interface Pilot: Facilitating Stakeholder Engagement in Connecting Research, Assessment and Risk Management

Christy Powers, PhD

National Center for Environmental Assessment
Office of Research and Development
Research Triangle Park, NC

RTI International's

"Nanomaterial Case Studies Workshop Process: Identifying and Prioritizing Research for Multiwalled Carbon Nanotubes"

October 29, 2012

Outline

- Vision and objective
- Current Status
- Looking Forward

The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

United States Environmental Protection Agency

Objective

→Facilitate Remote Stakeholder Engagement in Collective Judgement

Vision

Spreadsheet

Pilot

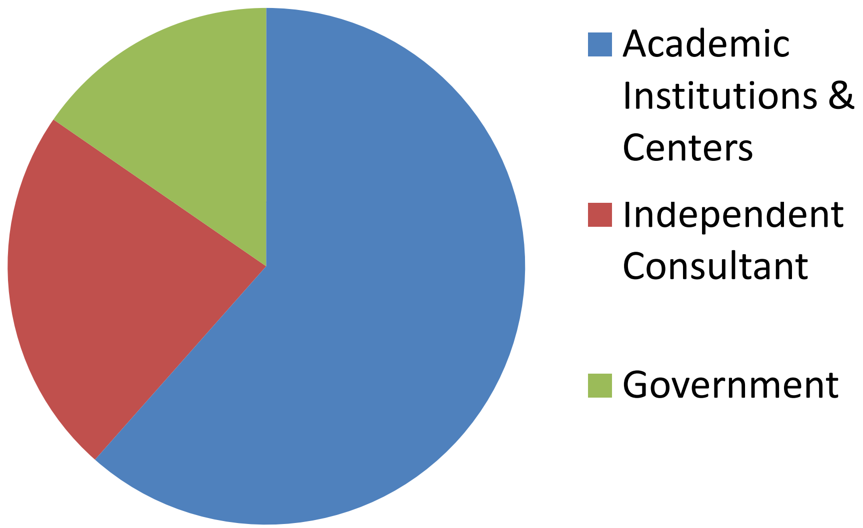
Future

→A "Smoother Ride": Remote stakeholder engagement

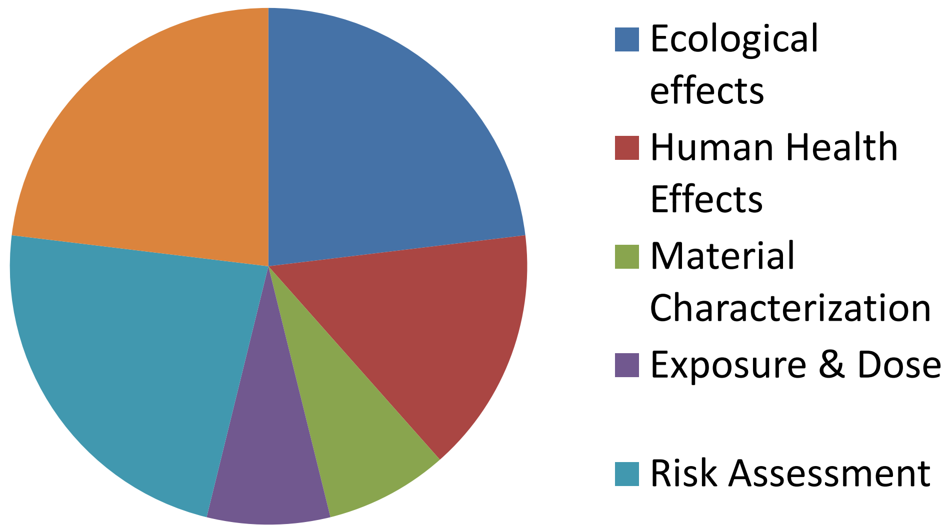
CEA Web Interface: Pilot

13 Participants Representing:

Sectors



Technical Expertise



→ Small, diverse group: Test Web Interface
→ Looks like?

CEA Web Interface: Pilot

→ Access

→ Home Page:
- o CEA
- o Pilot (webinar)
- o Draft case study
- o User guide

CEA Web Interface: Rating the Detailed Framework

United States Environmental Protection Agency

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bio-accumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

Dose (Kinetics)

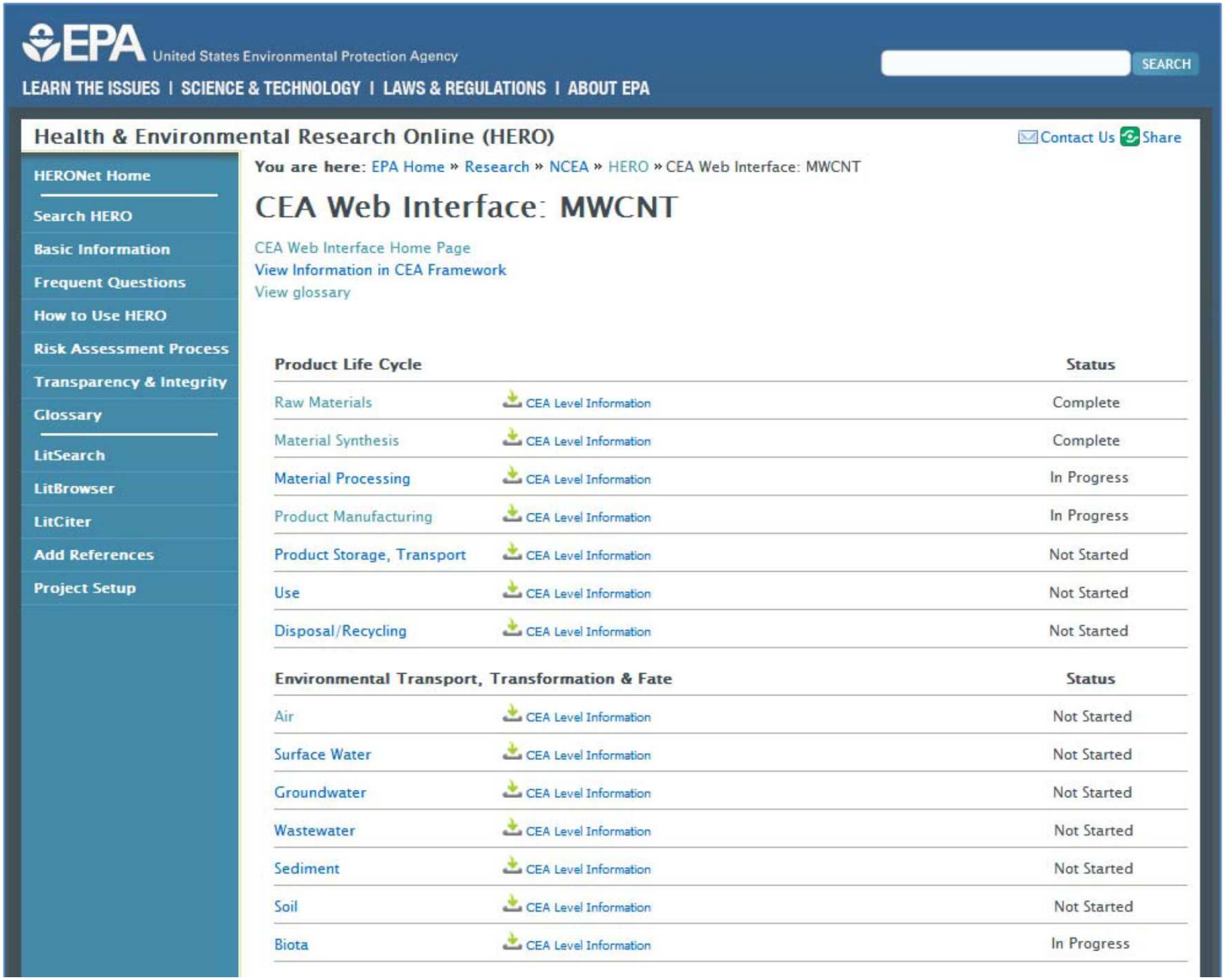
- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

EPA United States Environmental Protection Agency

CEA Web Interface: MWCNT



EPA United States Environmental Protection Agency

SEARCH

LEARN THE ISSUES | SCIENCE & TECHNOLOGY | LAWS & REGULATIONS | ABOUT EPA

Health & Environmental Research Online (HERO)

Contact Us Share

- HERONet Home
- Search HERO
- Basic Information
- Frequent Questions
- How to Use HERO
- Risk Assessment Process
- Transparency & Integrity
- Glossary
- LitSearch
- LitBrowser
- LitCiter
- Add References
- Project Setup

You are here: EPA Home » Research » NCEA » HERO » CEA Web Interface: MWCNT

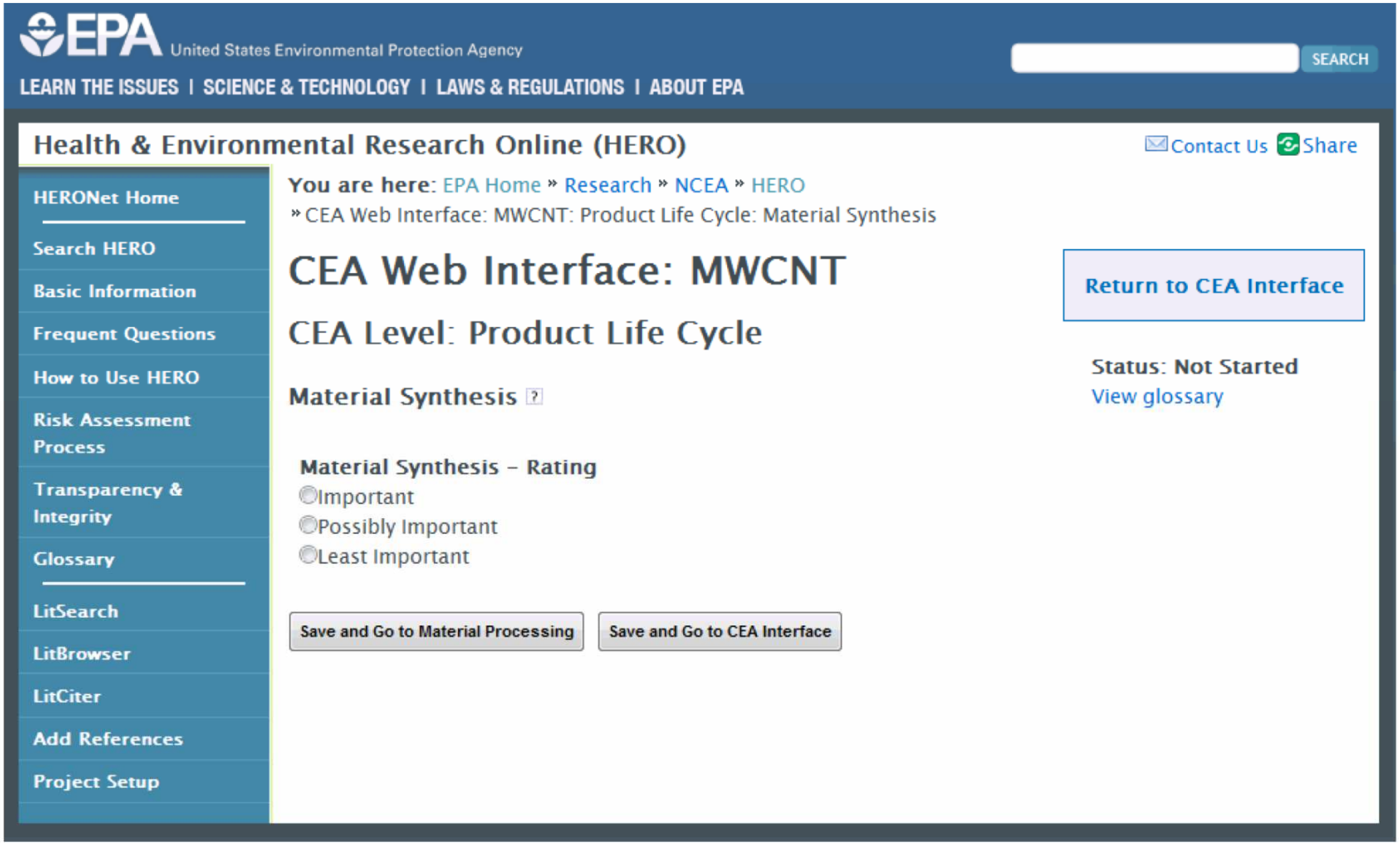
CEA Web Interface: MWCNT

CEA Web Interface Home Page
View Information in CEA Framework
View glossary

Product Life Cycle		Status
Raw Materials	CEA Level Information	Complete
Material Synthesis	CEA Level Information	Complete
Material Processing	CEA Level Information	In Progress
Product Manufacturing	CEA Level Information	In Progress
Product Storage, Transport	CEA Level Information	Not Started
Use	CEA Level Information	Not Started
Disposal/Recycling	CEA Level Information	Not Started

Environmental Transport, Transformation & Fate		Status
Air	CEA Level Information	Not Started
Surface Water	CEA Level Information	Not Started
Groundwater	CEA Level Information	Not Started
Wastewater	CEA Level Information	Not Started
Sediment	CEA Level Information	Not Started
Soil	CEA Level Information	Not Started
Biota	CEA Level Information	In Progress

CEA Web Interface: MWCNT – Rating the CEA Framework



United States Environmental Protection Agency

CEA Web Interface: MWCNT – Rating the CEA Framework

Rating

- (●) Important
- ( ) Possibly Important
- ( ) Least Important

Release Rate: Importance to Assessing Risk

- ( ) Important
- ( ) Possibly Important
- ( ) Least Important

Release Rate: Confidence in Data Availability and Utility for Assessing Risk

- ( ) Confident
- ( ) Somewhat Confident
- ( ) Not Confident

Why?

[Save and Go to Material Synthesis] [Save and Go to CEA Interface]

United States Environmental Protection Agency

CEA Web Interface: MWCNT – Rating Influential Factors

Product Storage, Transport – Release Rate: Influential Factors ?

(Note: Not all Influential Factors will be relevant to all CEA levels or to all Elements or Element/RRF pairs.)

Show All Checkboxes | Show Selected Checkboxes

Methods and Techniques

- ☐ Analytical Techniques
- ☐ Control Technologies
- ☐ MWCNT Processing Methods
- ☐ MWCNT Purity
- ☐ MWCNT Synthesis Methods
- ☐ Personal Protective Equipment
- ☐ Other

ENM Characteristics

- ☐ Adsorption/Desorption Ability
- ☐ Aggregation/Agglomeration State
- ☐ Applied Coatings
- ☐ Biodegradability
- ☐ Catalytic Activity
- ☐ Charge
- ☐ Conductive or Magnetic Properties
- ☐ Crystalline Phase
- ☐ Lipophilicity
- ☐ Matrix Bound vs. Free
- ☐ Morphology (e.g. aspect ratio, length, width, shape)
- ☐ Persistence
- ☐ Redox Potential
- ☐ Size/Size Distribution
- ☐ Specific Surface Area
- ☐ Structural Formula/Molecular Structure
- ☐ Surface Chemistry
- ☐ Water Solubility/Dispersibility
- ☐ Other

Environmental Conditions – Chemical Conditions

- ☐ Conductivity
- ☐ Dispersing Agents
- ☐ Dissolved Oxygen Content
- ☐ Exposure to Sunlight
- ☐ Heavy Metals in Environment
- ☐ Ionic Strength in Environment
- ☐ Ligand Concentrations in Environment
- ☐ Natural Organic Matter (NOM)
- ☐ Other Contaminants in Environment
- ☐ pH
- ☐ Protein Concentration in Environment
- ☐ Salinity
- ☐ Surfactant (in Lab)
- ☐ Other

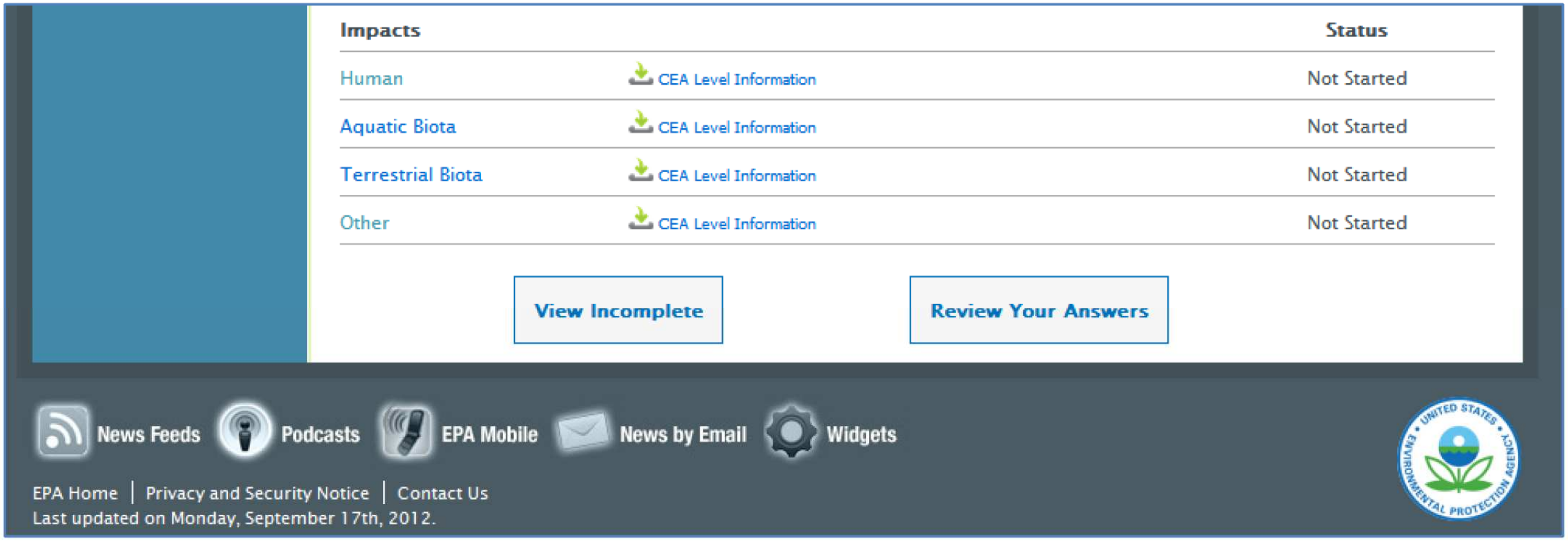
Environmental Conditions – Biological Conditions

- ☐ ADME
- ☐ Bioaccumulation
- ☐ Biomagnification
- ☐ Microbial Communities in Environment
- ☐ Organism Health
- ☐ Species/Individual Developmental Behavior
- ☐ Species/Individual Feeding Behavior
- ☐ Species/Individual Reproductive Behavior
- ☐ Other

Environmental Conditions – Social Conditions

- ☐ Acute Exposure
- ☐ Chronic Exposure

CEA Web Interface: Progress



CEA Web Interface: MWCNT – Progress

Exposure Route		Status
Human: Occupational	CEA Level Information	Complete
Human: Consumer	CEA Level Information	Complete
Human: General Population	CEA Level Information	Complete
Aquatic Biota	CEA Level Information	Complete
Terrestrial Biota	CEA Level Information	Complete
Abiotic	CEA Level Information	Complete

Dose (Kinetics)		Status
Human	CEA Level Information	Complete
Aquatic Biota	CEA Level Information	Complete
Terrestrial Biota	CEA Level Information	Complete
Abiotic	CEA Level Information	Complete

Impacts		Status
Human	CEA Level Information	Complete
Aquatic Biota	CEA Level Information	Complete
Terrestrial Biota	CEA Level Information	Complete
Other	CEA Level Information	Complete

Review Your Answers

Complete Project Review

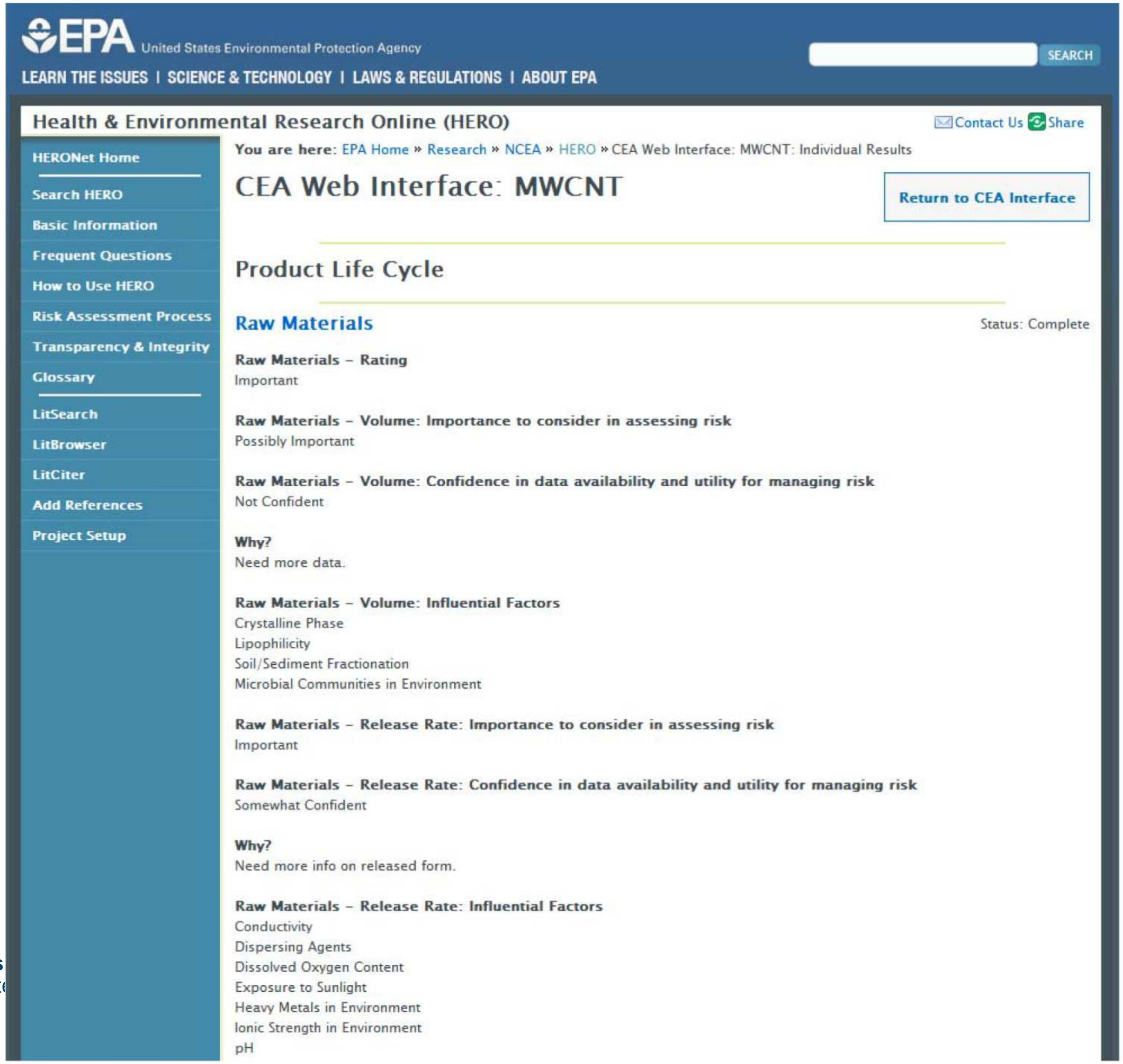
News Feeds Podcasts EPA Mobile News by Email Widgets

EPA Home | Privacy and Security Notice | Contact Us

Last updated on Monday, September 17th, 2012.

EPA United States Environmental Protection Agency

CEA Web Interface: MWCNT – Review Answers


EPA United States Environmental Protection Agency

SEARCH

LEARN THE ISSUES | SCIENCE & TECHNOLOGY | LAWS & REGULATIONS | ABOUT EPA

Health & Environmental Research Online (HERO)

Contact Us Share

HERONet Home
Search HERO
Basic Information
Frequent Questions
How to Use HERO
Risk Assessment Process
Transparency & Integrity
Glossary
LitSearch
LitBrowser
LitCiter
Add References
Project Setup

You are here: EPA Home » Research » NCEA » HERO » CEA Web Interface: MWCNT: Individual Results

CEA Web Interface: MWCNT

Return to CEA Interface

Product Life Cycle

Raw Materials

Status: Complete

Raw Materials – Rating
Important

Raw Materials – Volume: Importance to consider in assessing risk
Possibly Important

Raw Materials – Volume: Confidence in data availability and utility for managing risk
Not Confident

Why?
Need more data.

Raw Materials – Volume: Influential Factors
Crystalline Phase
Lipophilicity
Soil/Sediment Fractionation
Microbial Communities in Environment

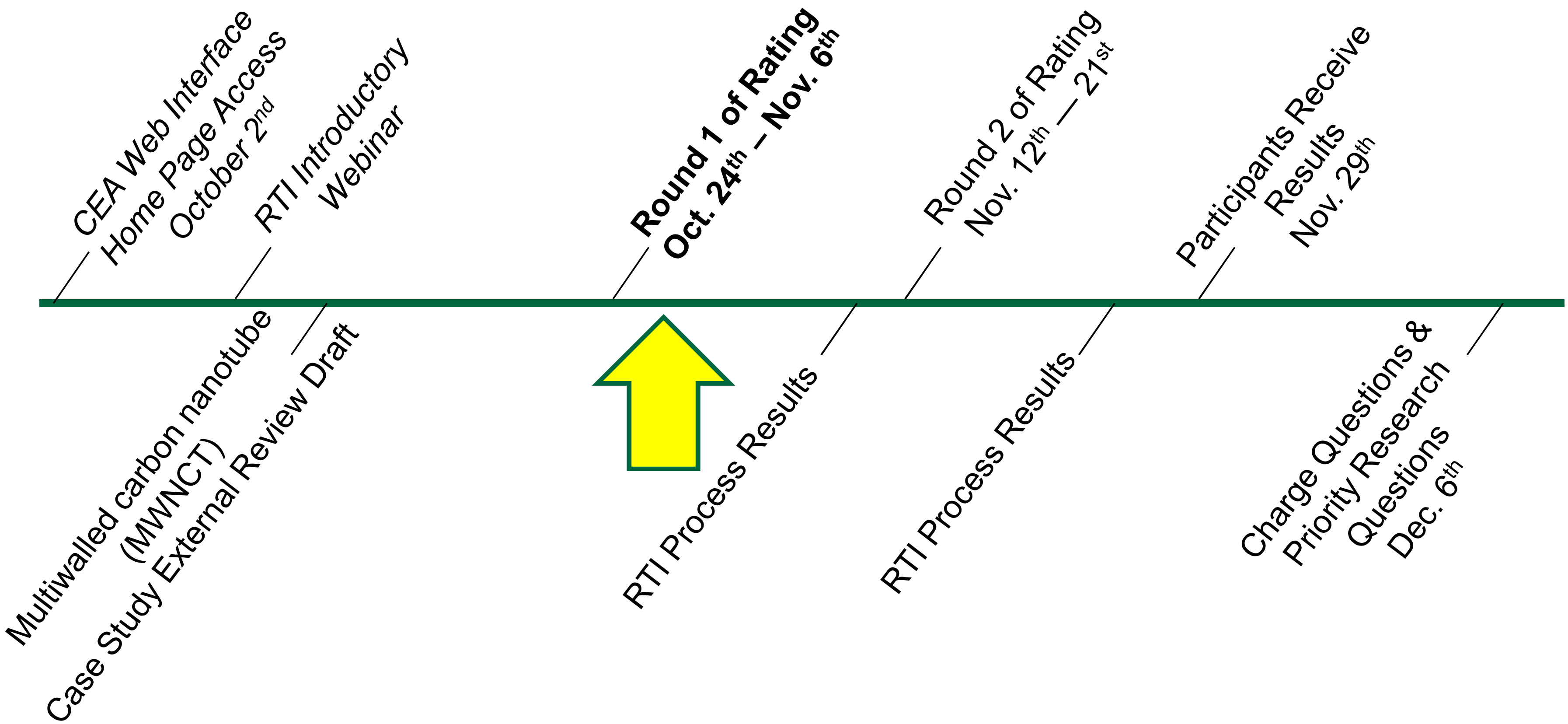
Raw Materials – Release Rate: Importance to consider in assessing risk
Important

Raw Materials – Release Rate: Confidence in data availability and utility for managing risk
Somewhat Confident

Why?
Need more info on released form.

Raw Materials – Release Rate: Influential Factors
Conductivity
Dispersing Agents
Dissolved Oxygen Content
Exposure to Sunlight
Heavy Metals in Environment
Ionic Strength in Environment
pH

CEA Web Interface Pilot: Next Steps



CEA Web Interface Pilot: Looking Forward

- Participant feedback
- Expand → Risk Trade-off Prioritization
- Existing databases and models

The CEA Strategy Team

Lyle Burgoon , PhD

Meredith Lassiter, PhD

Geniece Lehmann, PhD

Jeff Gift, PhD

Patricia Gillespie, PhD

Emma McConnell

Kyle Painter

Christy Powers, PhD

United States Environmental Protection Agency

Thanks!

Questions and Discussion!

Extra Slides

CEA Web Interface: MWCNT

Demo

CEA Web Interface: MWCNT

https://hero.epa.gov/index.cfm?action=cea.main

Comprehensive Environmental Assessment Applied to Nanocarbon:

Review of Results from Round 3

30 October 2012

CEA MWCNT Prioritization Tool: Analytical Results

WHO: All Participants

WHEN: June 26th, 27th — Early July — Late July — Early August — Mid August

WHAT:
1. Attend Webinar
2. Receive Case Study
3. Pre-Test on Case Study Review
4. Round 1 Prioritization
5. Review Round 1 Responses
6. Round 2 Prioritization
7. Review Round 2 Responses
8. Submit Answers to Charge Questions

WHO: Sub-set of Participants with Expertise in Prioritized Research Areas

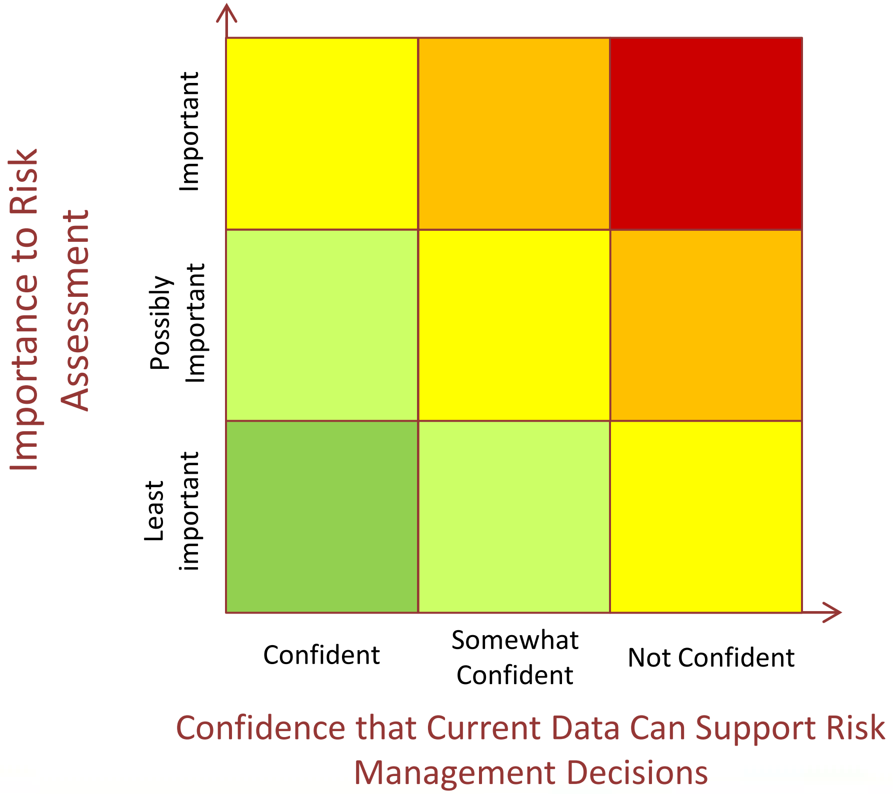
WHEN: Late August — Workshop October 29th, 30th, 31st — February 2013

WHAT:
9. Invited to Workshop
10. NGT Round Robin Discussion
11. Round 3 Prioritization
12. Build Detailed Research Questions
13. Receive Access to Final Report

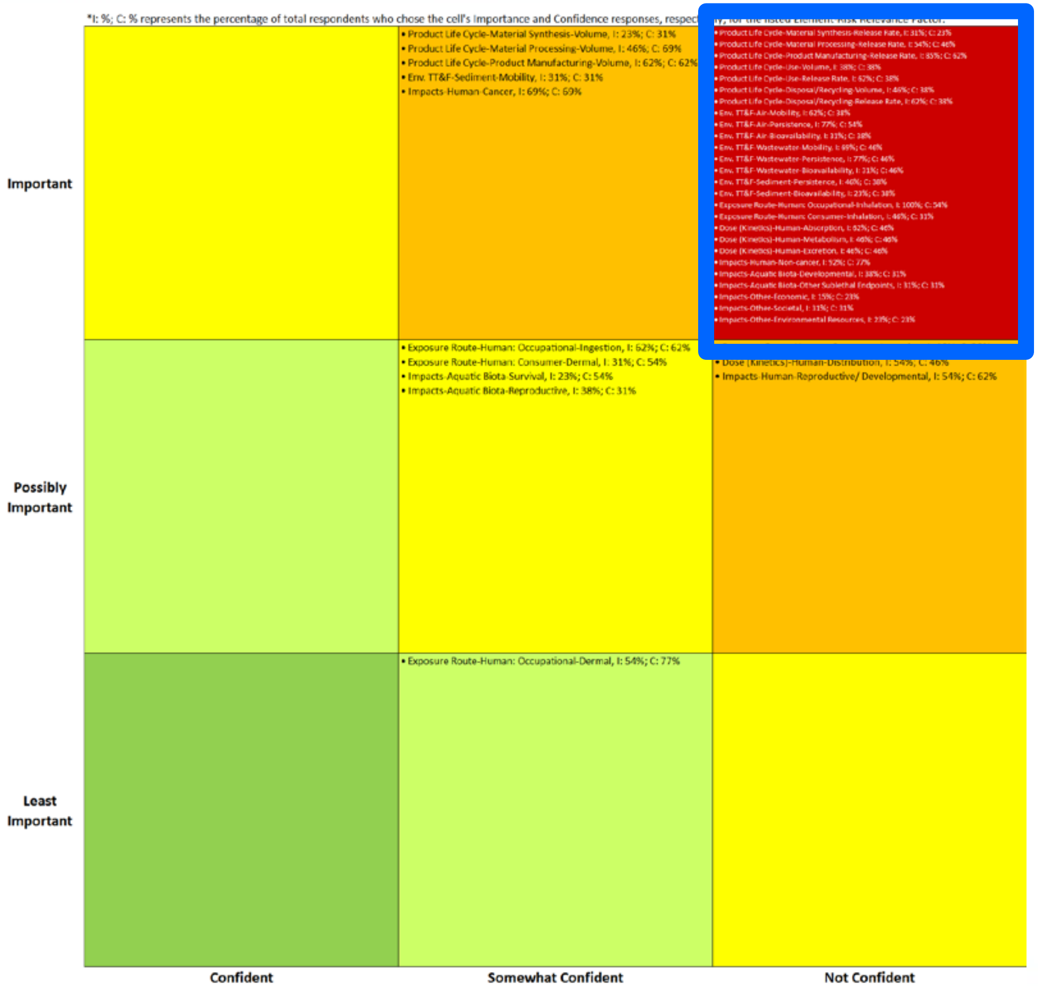
YOU ARE HERE

CEA MWCNT Prioritization Tool Output

- Research areas falling into red or orange boxes of the CEA Prioritization Matrix will be elevated for development of research questions by experts during the Final Workshop (CEA Prioritization Round 3).



Results of Round 3: Importance/Confidence Matrix



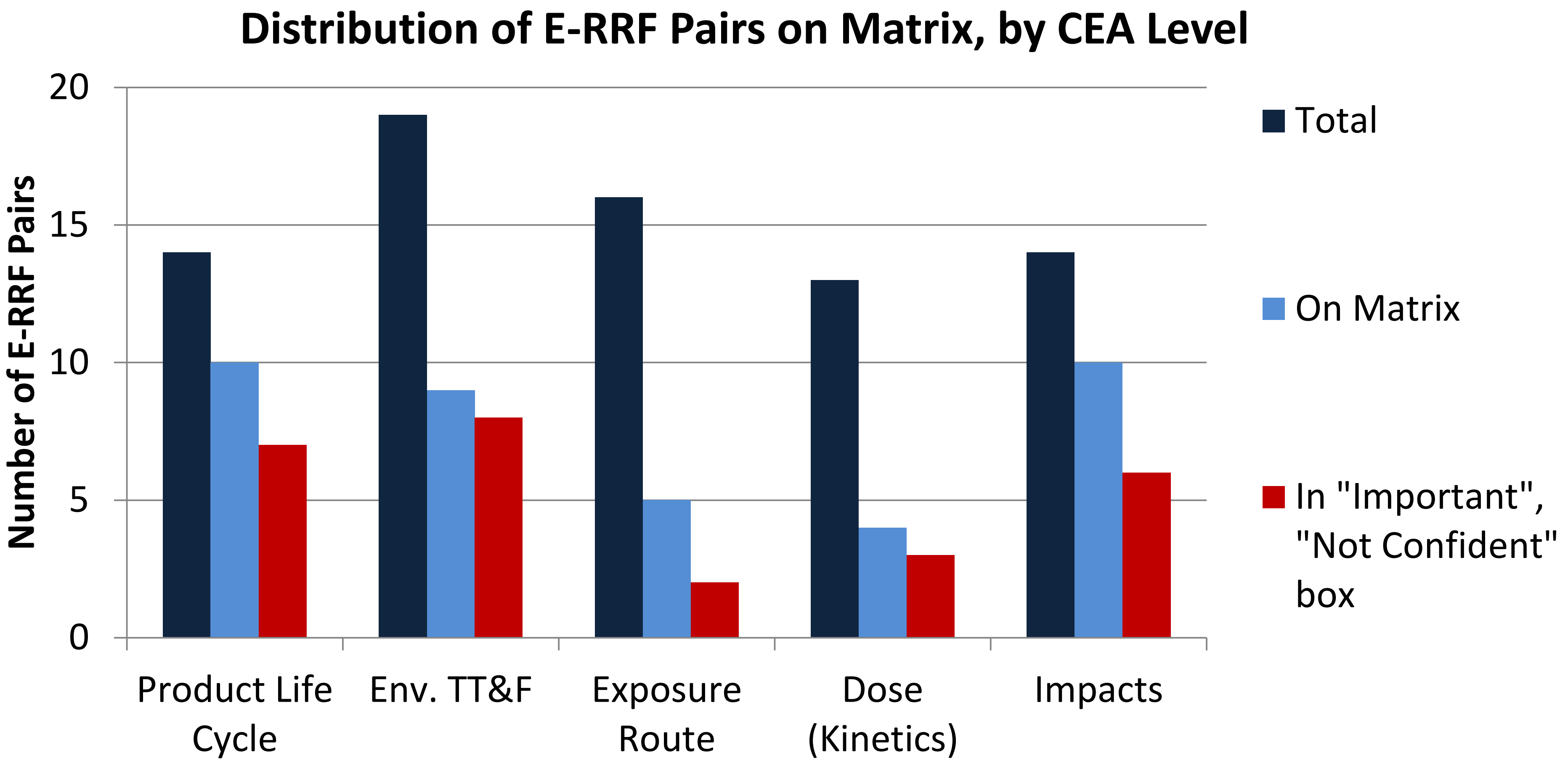
- A large majority (but smaller than in both of the first 2 Rounds) of E-RRF pairs on the Matrix were grouped into the highest priority (red) bin
  - "Important", "Not Confident"
  - 26 / 39
  - 67%

Results of Round 3: Importance/Confidence Matrix

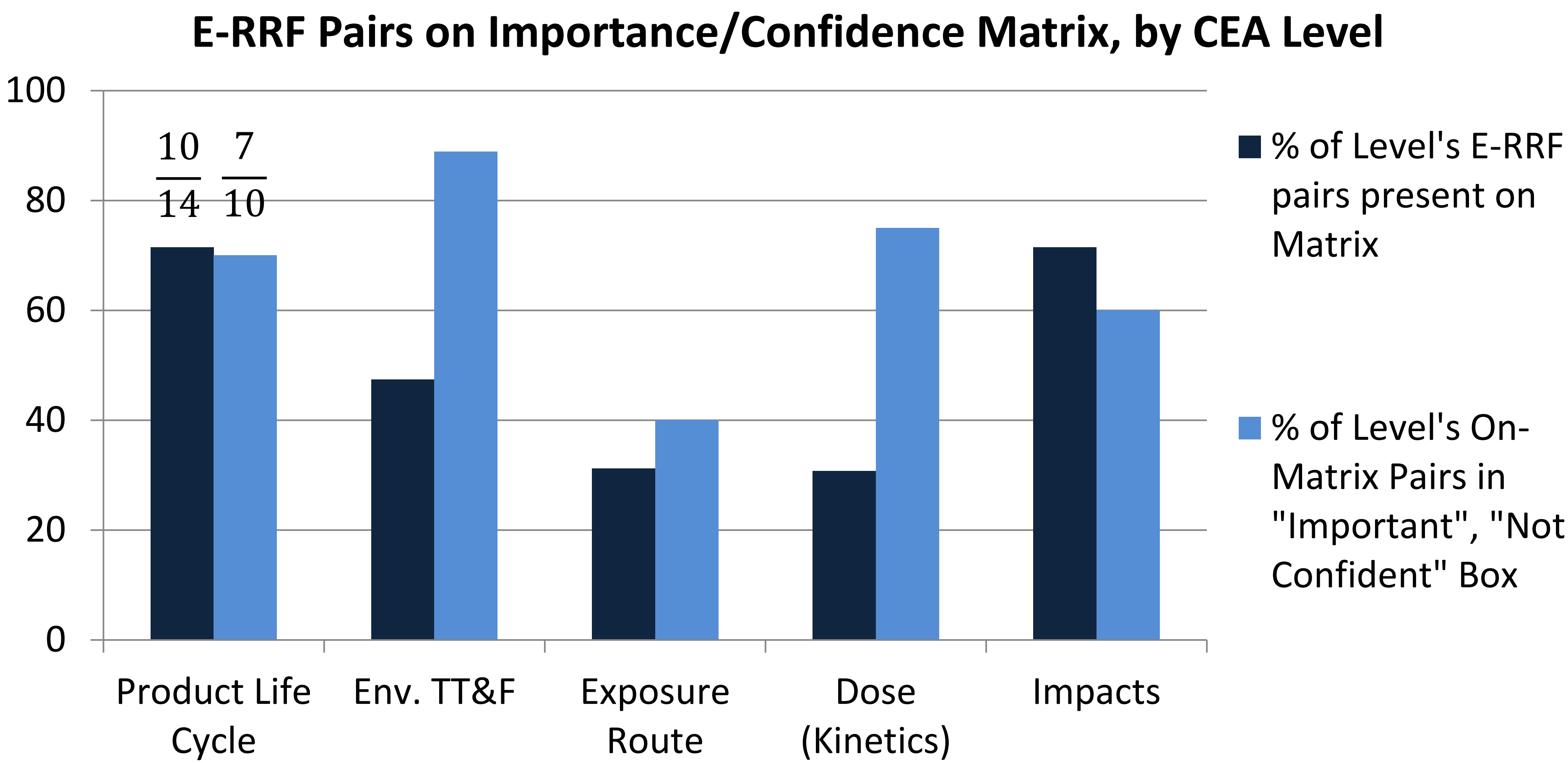
- Product Life Cycle-Material Synthesis-Release Rate, I: 31%; C: 23%
- Product Life Cycle-Material Processing-Release Rate, I: 54%; C: 46%
- Product Life Cycle-Product Manufacturing-Release Rate, I: 85%; C: 62%
- Product Life Cycle-Use-Volume, I: 38%; C: 38%
- Product Life Cycle-Use-Release Rate, I: 62%; C: 38%
- Product Life Cycle-Disposal/Recycling-Volume, I: 46%; C: 38%
- Product Life Cycle-Disposal/Recycling-Release Rate, I: 62%; C: 38%
- Env. TT&F-Air-Mobility, I: 62%; C: 38%
- Env. TT&F-Air-Persistence, I: 77%; C: 54%
- Env. TT&F-Air-Bioavailability, I: 31%; C: 38%
- Env. TT&F-Wastewater-Mobility, I: 69%; C: 46%
- Env. TT&F-Wastewater-Persistence, I: 77%; C: 46%
- Env. TT&F-Wastewater-Bioavailability, I: 31%; C: 46%
- Env. TT&F-Sediment-Persistence, I: 46%; C: 38%
- Env. TT&F-Sediment-Bioavailability, I: 23%; C: 38%
- Exposure Route-Human: Occupational-Inhalation, I: 100%; C: 54%
- Exposure Route-Human: Consumer-Inhalation, I: 46%; C: 31%
- Dose (Kinetics)-Human-Absorption, I: 62%; C: 46%
- Dose (Kinetics)-Human-Metabolism, I: 46%; C: 46%
- Dose (Kinetics)-Human-Excretion, I: 46%; C: 46%
- Impacts-Human-Non-cancer, I: 92%; C: 77%
- Impacts-Aquatic Biota-Developmental, I: 38%; C: 31%
- Impacts-Aquatic Biota-Other Sublethal Endpoints, I: 31%; C: 31%
- Impacts-Other-Economic, I: 15%; C: 23%
- Impacts-Other-Societal, I: 31%; C: 31%
- Impacts-Other-Environmental Resources, I: 23%; C: 23%

- All 5 CEA Levels represented in highest-priority box

Results of Round 3: Importance/Confidence Matrix

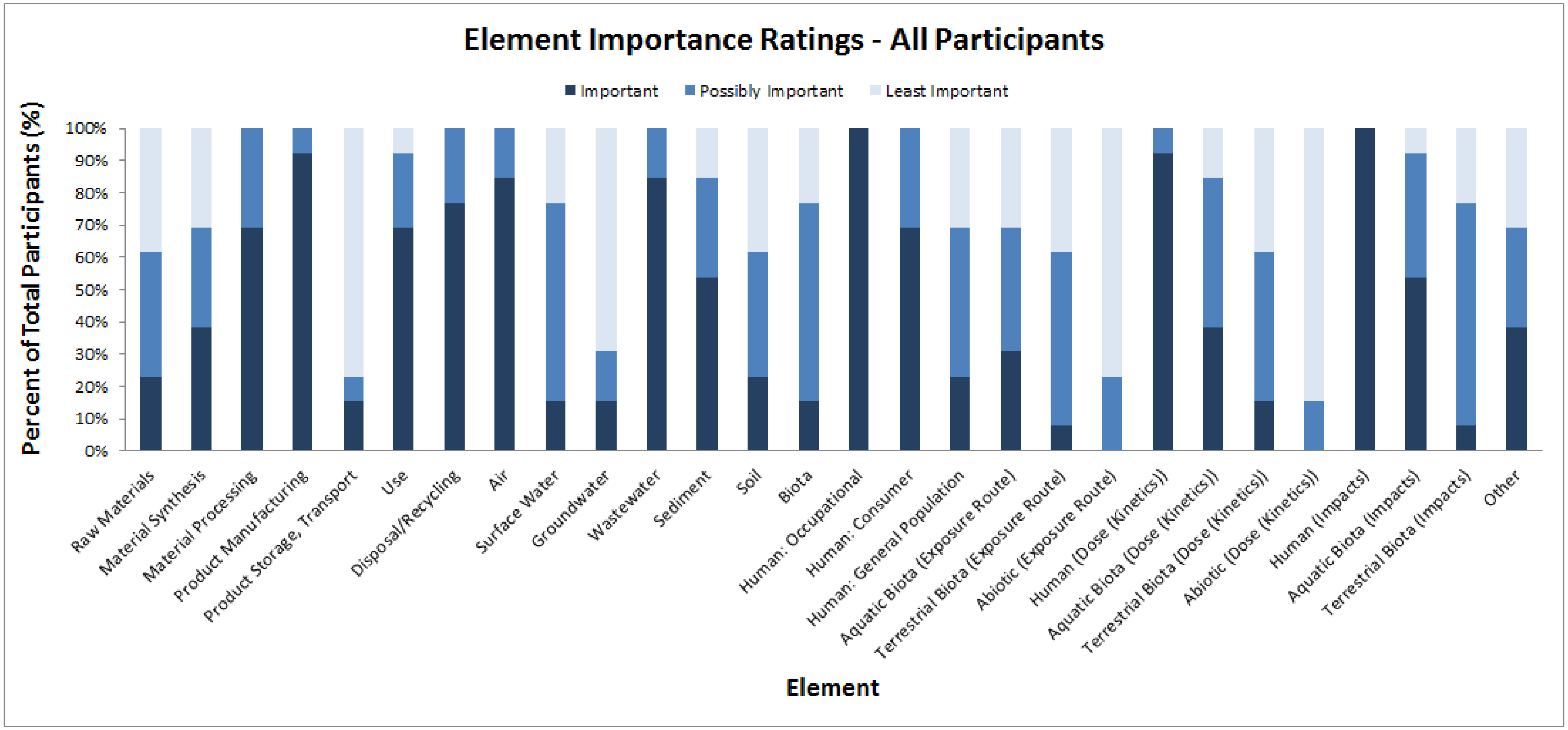


Results of Round 3: Importance/Confidence Matrix



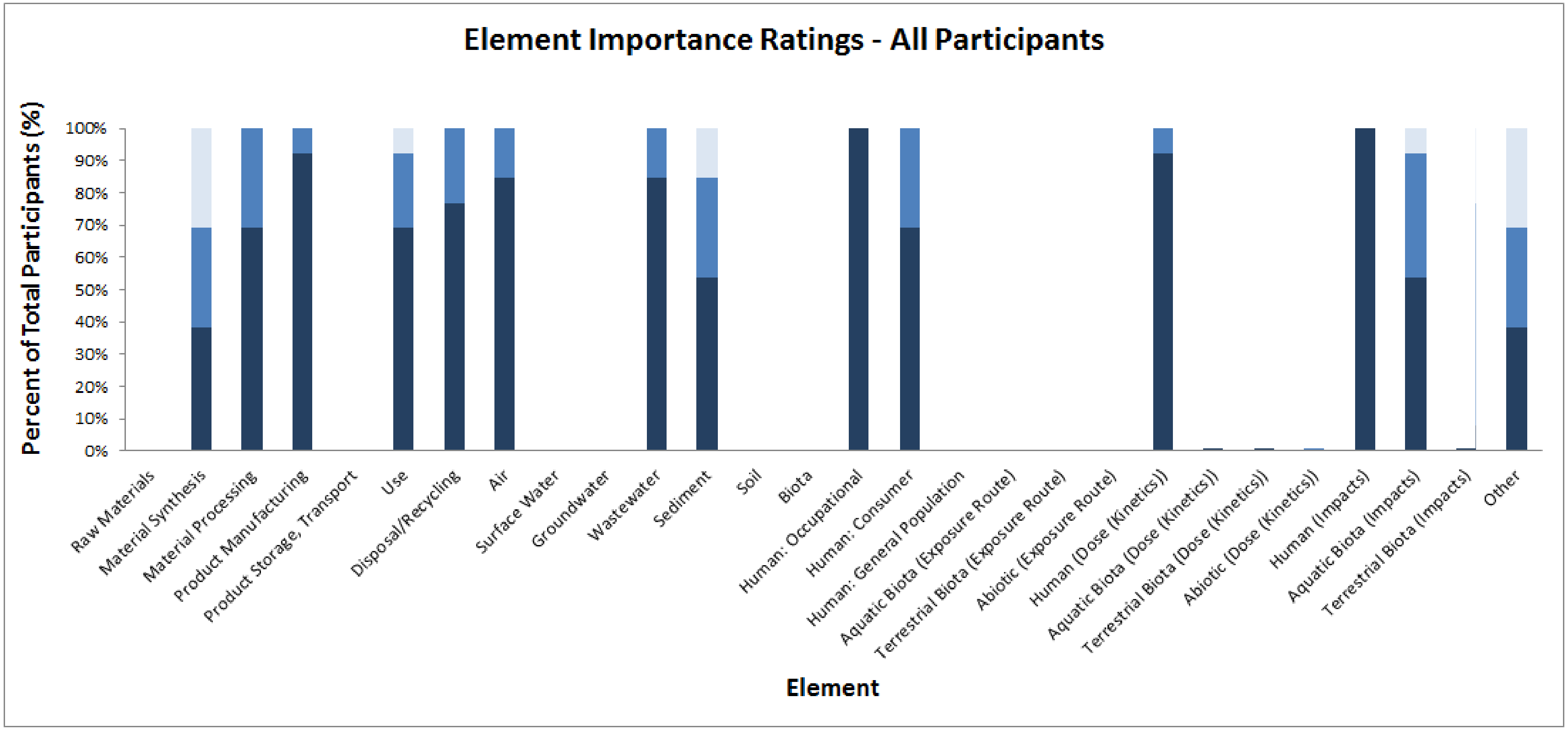
Results of Round 3: Element Importance Ratings

Important | Possibly Important | Least Important

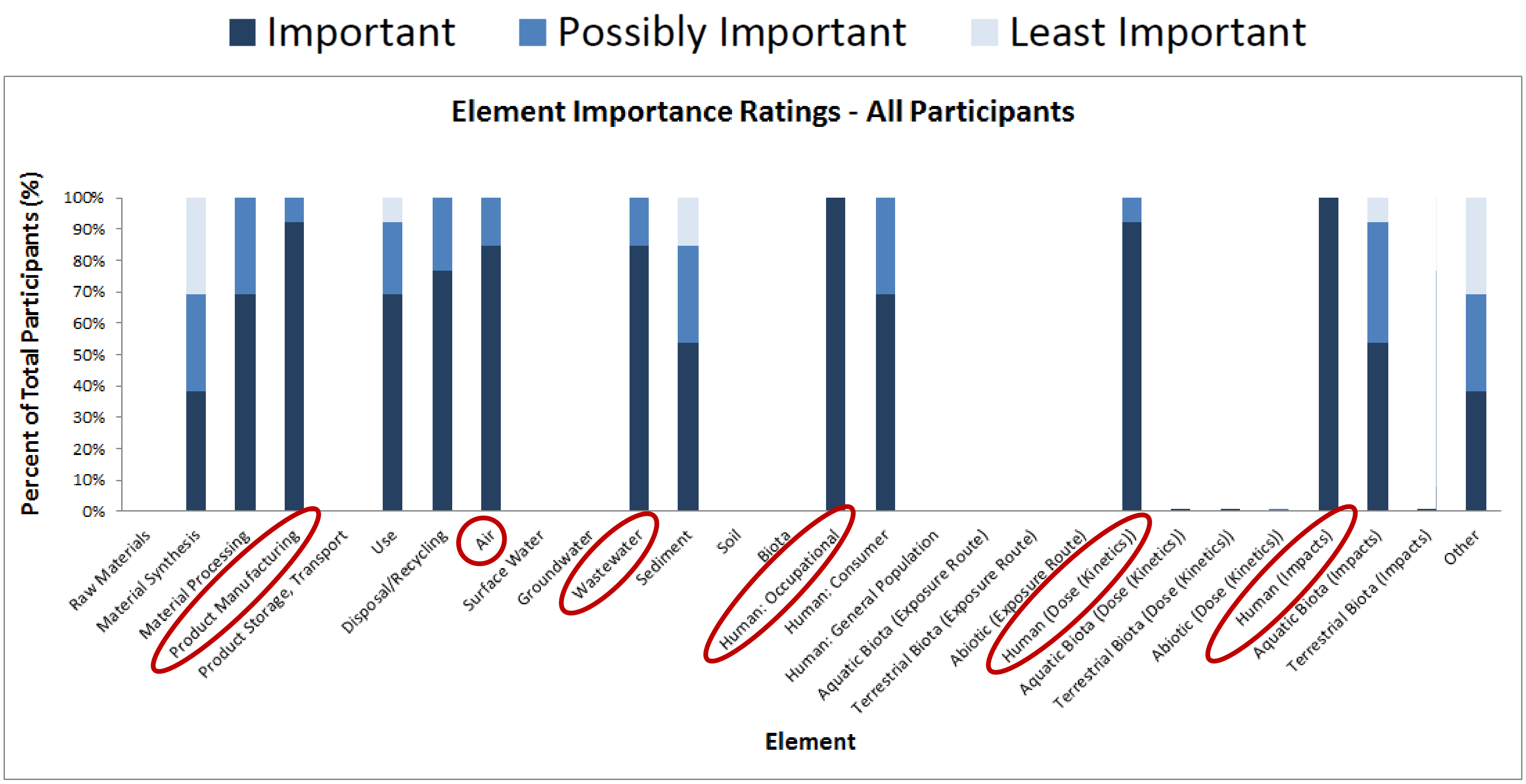


Results of Round 3: Element Importance Ratings, On-Matrix

Important | Possibly Important | Least Important



Results of Round 3: Element Importance Ratings, Top 6



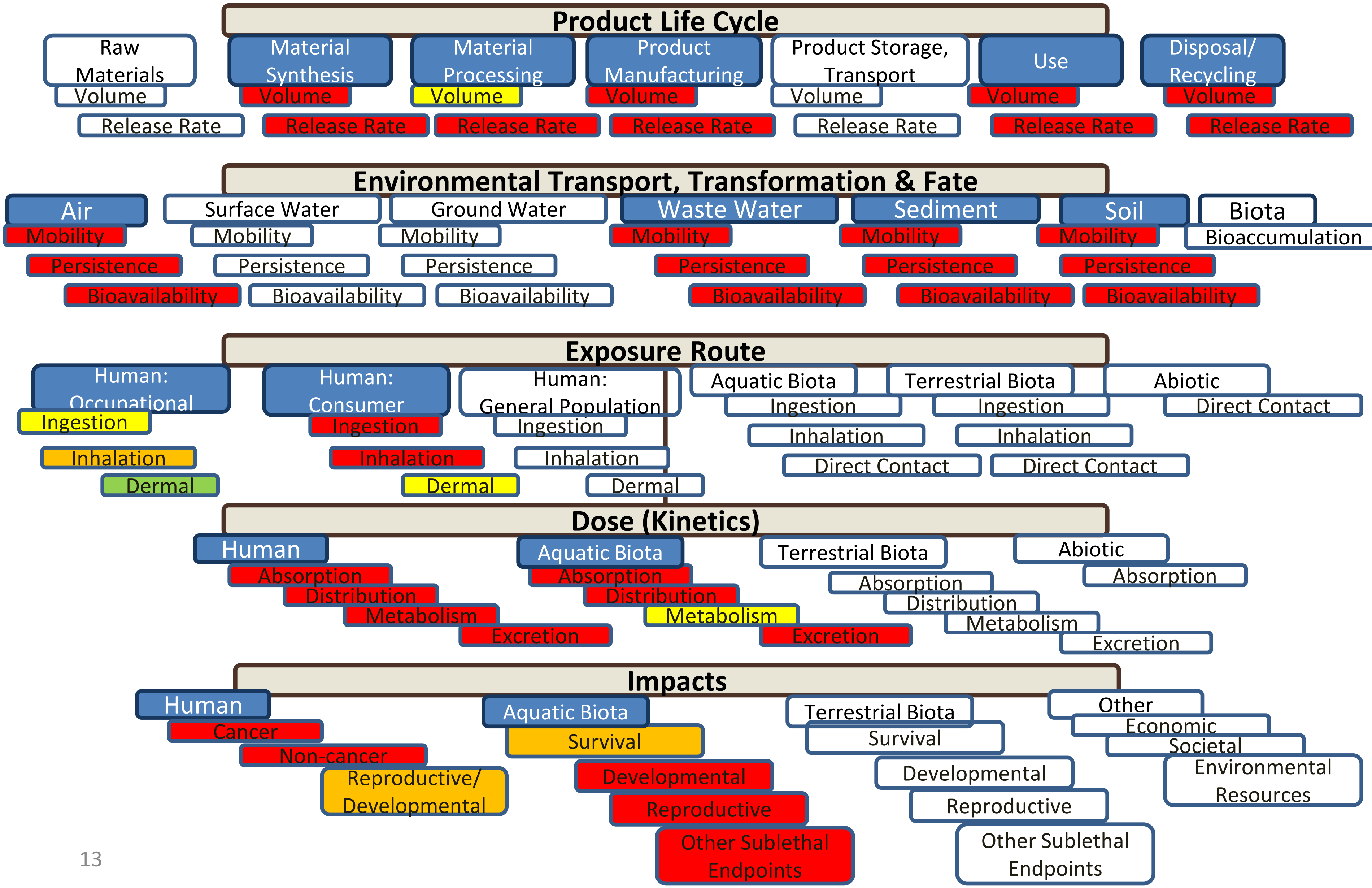
Changes from Round 1 to Round 2

CEA Level	Number of E-RRF Pairs	Number of E-RRF Pairs in "Important", "Not Confident" Bin			Percent of E-RRF Pairs in "Important", "Not Confident" Bin		
		Round 1	Round 2	**Change**	Round 1	Round 2	**Change**
Product Life Cycle	14	6	9	**+3**	43%	64%	**+21**
Environmental Transport, Transformation & Fate	19	13	12	**-1**	68%	63%	**-5**
Exposure Route	16	2	2	**0**	13%	13%	**0**
Dose (Kinetics)	13	8	7	**-1**	62%	54%	**-8**
Impacts	14	5	5	**0**	36%	36%	**0**

Changes from Round 2 to Round 3

CEA Level	Number of E-RRF Pairs	Number of E-RRF Pairs in "Important", "Not Confident" Bin			Percent of E-RRF Pairs in "Important", "Not Confident" Bin		
		Round 2	Round 3	**Change**	Round 2	Round 3	**Change**
Product Life Cycle	14	9	7	**-2**	64%	50%	**-14**
Environmental Transport, Transformation & Fate	19	12	8	**-4**	63%	42%	**-21**
Exposure Route	16	2	2	**0**	13%	13%	**0**
Dose (Kinetics)	13	7	3	**-4**	54%	23%	**-31**
Impacts	14	5	6	**+1**	36%	43%	**+7**

Results of Round 2:



Results of Round 3: Breakout Groups

Product Life Cycle

- **Raw Materials**: Volume; Release Rate
- **Material Synthesis**: Volume; Release Rate
- **Material Processing**: Volume; Release Rate
- **Product Manufacturing**: Volume; Release Rate
- **Product Storage, Transport**: Volume; Release Rate
- **Use**: Volume; Release Rate
- **Disposal/ Recycling**: Volume; Release Rate

Environmental Transport, Transformation & Fate

- **Air**: Mobility; Persistence; Bioavailability
- **Surface Water**: Mobility; Persistence; Bioavailability
- **Ground Water**: Mobility; Persistence; Bioavailability
- **Waste Water**: Mobility; Persistence; Bioavailability
- **Sediment**: Mobility; Persistence; Bioavailability
- **Soil**: Mobility; Persistence; Bioavailability
- **Biota**: Bioaccumulation

Exposure Route

- **Human: Occupational**: Ingestion; Inhalation; Dermal
- **Human: Consumer**: Ingestion; Inhalation; Dermal
- **Human: General Population**: Ingestion; Inhalation; Dermal
- **Aquatic Biota**: Ingestion; Inhalation; Direct Contact
- **Terrestrial Biota**: Ingestion; Inhalation; Direct Contact
- **Abiotic**: Direct Contact

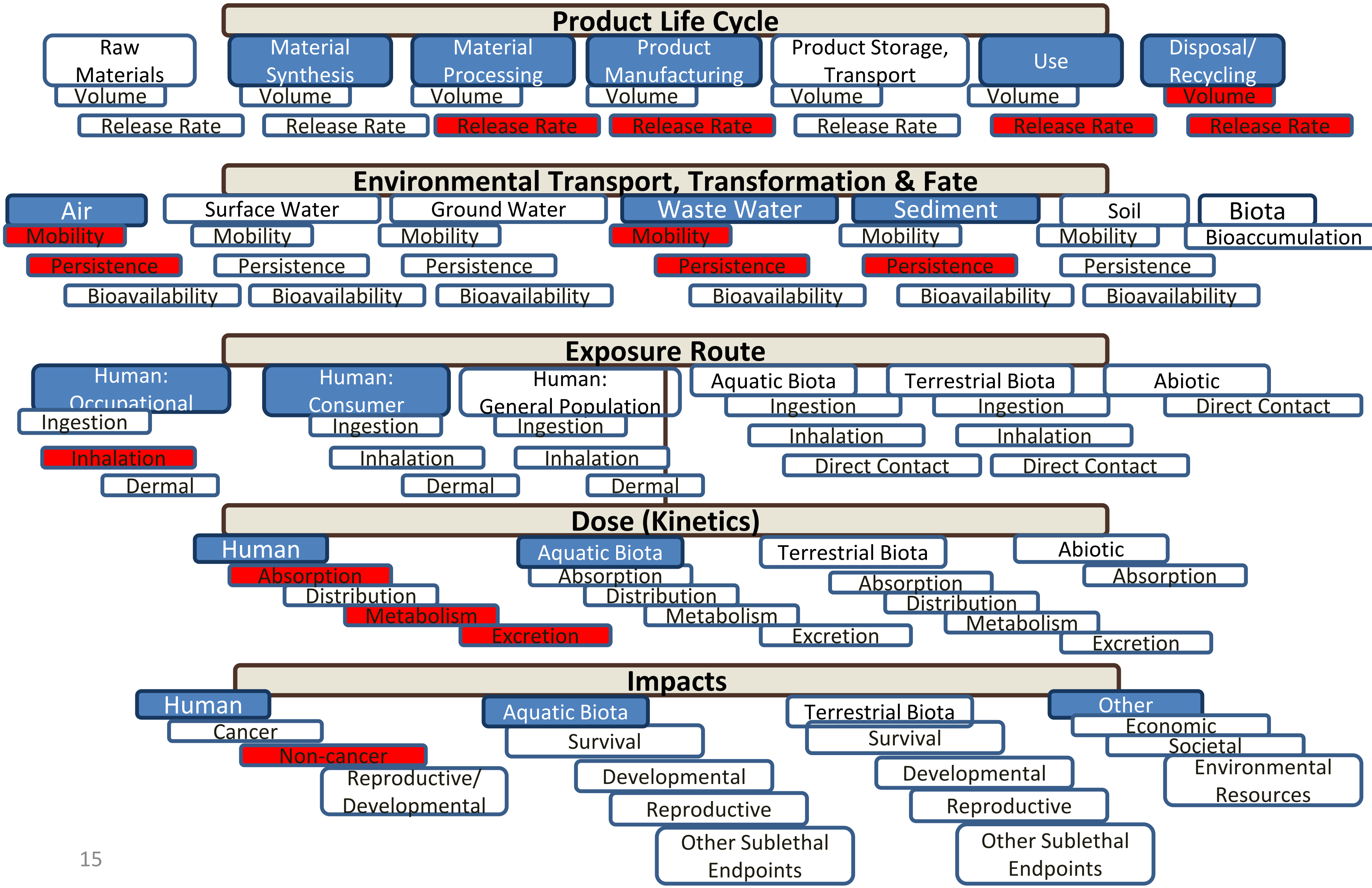
Dose (Kinetics)

- **Human**: Absorption; Distribution; Metabolism; Excretion
- **Aquatic Biota**: Absorption; Distribution; Metabolism; Excretion
- **Terrestrial Biota**: Absorption; Distribution; Metabolism; Excretion
- **Abiotic**: Absorption

Impacts

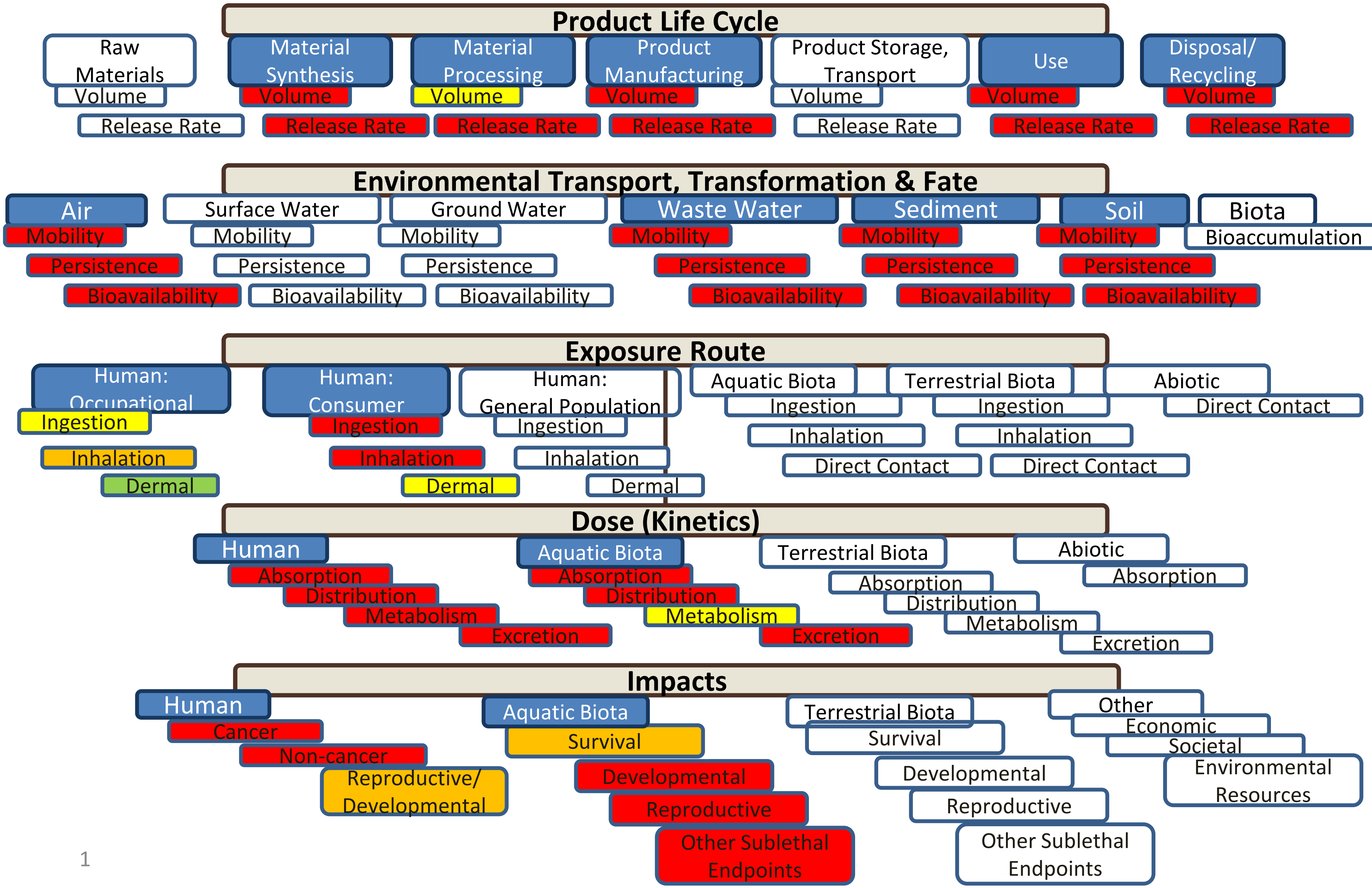
- **Human**: Cancer; Non-cancer; Reproductive/ Developmental
- **Aquatic Biota**: Survival; Developmental; Reproductive; Other Sublethal Endpoints
- **Terrestrial Biota**: Survival; Developmental; Reproductive; Other Sublethal Endpoints
- **Other**: Economic; Societal; Environmental Resources

Results of Round 3:



ID	E-RRF Pair	Dist from O Rank (INC only)
64	Human-Non-cancer	1
35	Human: Occupational-Inhalation	2
8	Product Manufacturing-Release Rate	3
16	Air-Persistence	4
25	Wastewater-Persistence	5
24	Wastewater-Mobility	6
50	Human-Absorption	7
12	Use-Release Rate	8
14	Disposal/Recycling-Release Rate	9
15	Air-Mobility	10
6	Material Processing-Release Rate	11
52	Human-Metabolism	12
53	Human-Excretion	13
13	Disposal/Recycling-Volume	14
28	Sediment-Persistence	15
26	Wastewater-Bioavailability	16
38	Human: Consumer-Inhalation	17
11	Use-Volume	18
17	Air-Bioavailability	19
67	Aquatic Biota-Developmental	20
29	Sediment-Bioavailability	21
69	Aquatic Biota-Other Sublethal Endpoints	22
75	Other-Societal	23
4	Material Synthesis-Release Rate	24
76	Other-Environmental Resources	25
74	Other-Economic	26

Results of Round 2:



Results of Round 3: Breakout Groups

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bioaccumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

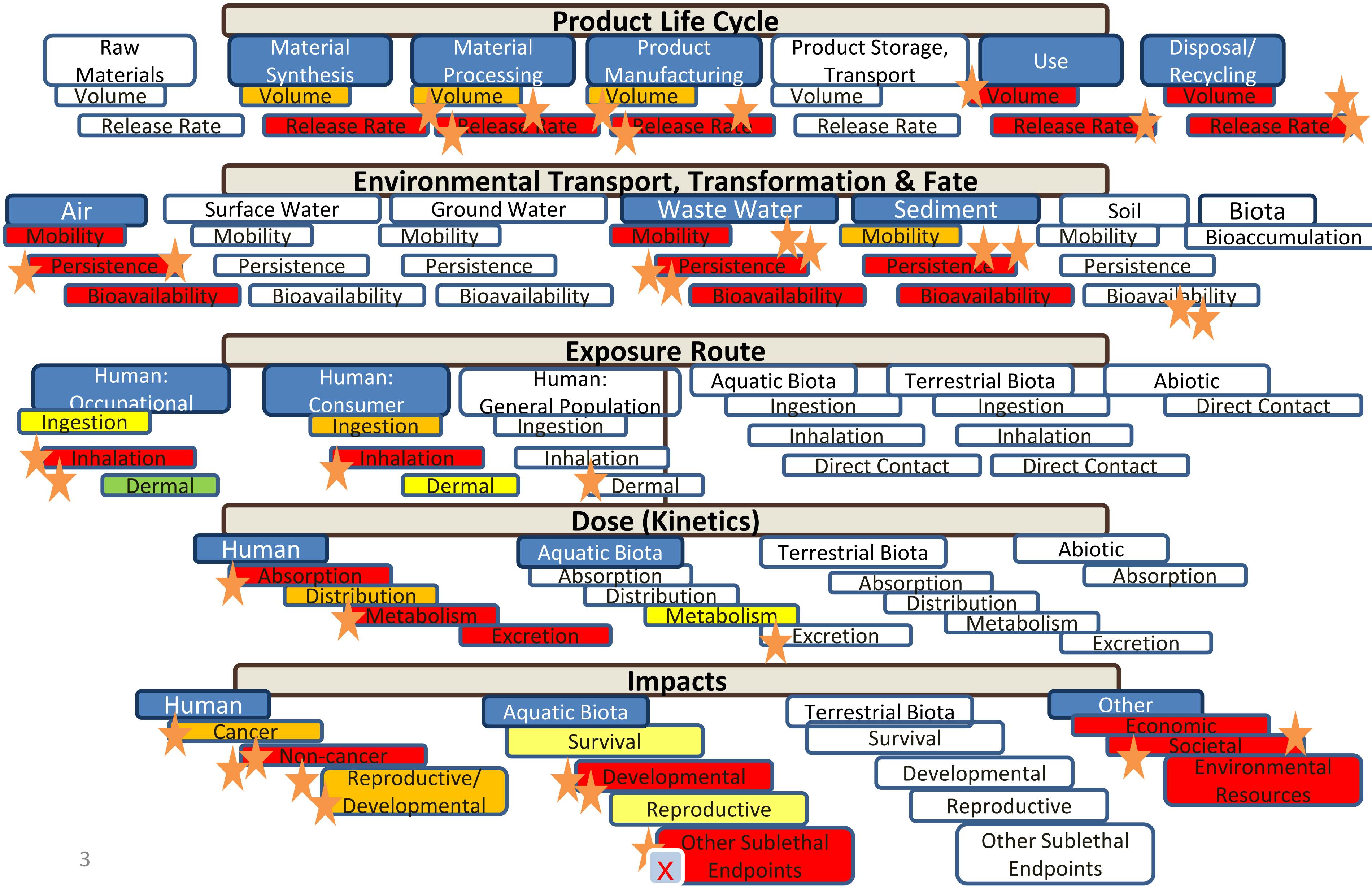
Dose (Kinetics)

- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

Results of Round 3: Breakout Groups



Results of Round 3:

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bioaccumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

Dose (Kinetics)

- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

Results of Round 3:

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bioaccumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

Dose (Kinetics)

- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

X

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Workshop Output

October 30, 2012

Why We're Here

- Meet the challenge of science-based decision support with a direct approach to linking:

  Research → Assessments → Risk Management

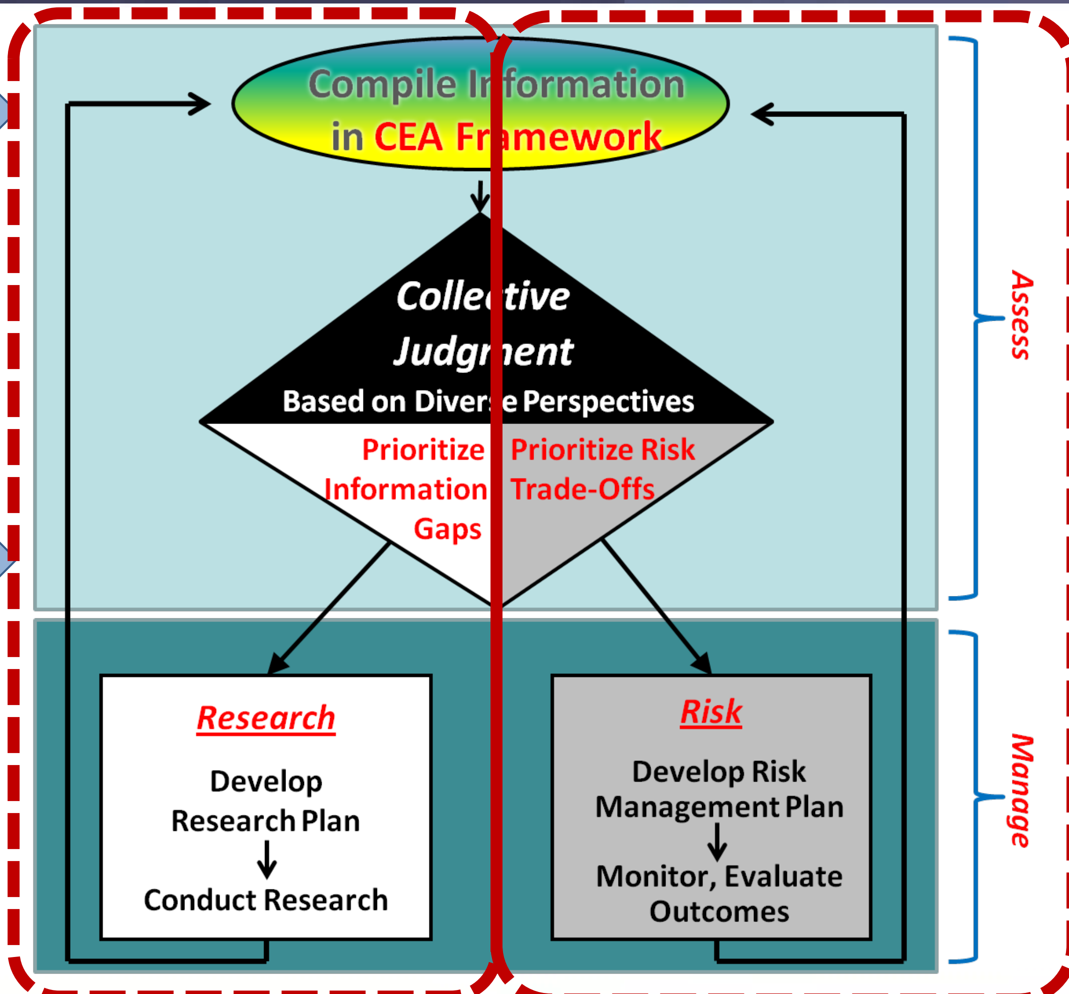
- Make recommendations through a process incorporating collective wisdom

- Utilize this "lab" of diverse minds tackling a challenging complex issue to create a USEFUL output to guide the nanoEHS research community.

CEA Approach: Process

Case Study Document

CEA Prioritization Exercises



Purpose of the Current Application is to Support Research to Enable Risk Management.

CEA MWCNT Prioritization Process

Nanoscale Carbon Case Study

CEA Prioritization Round 1

All participants rate the CEA Framework based on:
- Importance to risk assessment
- Confidence in data to support risk management decisions

Analyzed Round 1 Ratings

CEA Prioritization Round 2

All participants re-rate the CEA Framework based on:
- Importance to risk assessment
- Confidence in data to support risk management decisions

Analyzed Round 2 Ratings

Generation of Research Question Starter Set

All participants generate top three research questions for the prioritized areas

Analyzed Round 2 Ratings

Research Question Starter Set

Final Workshop:
- CEA Prioritization Round 3
- Generation of Final Research Questions

Experts specialized in prioritized areas use NGT to nominate priority research areas.
Participants work individually to re-rate the CEA Framework a third time

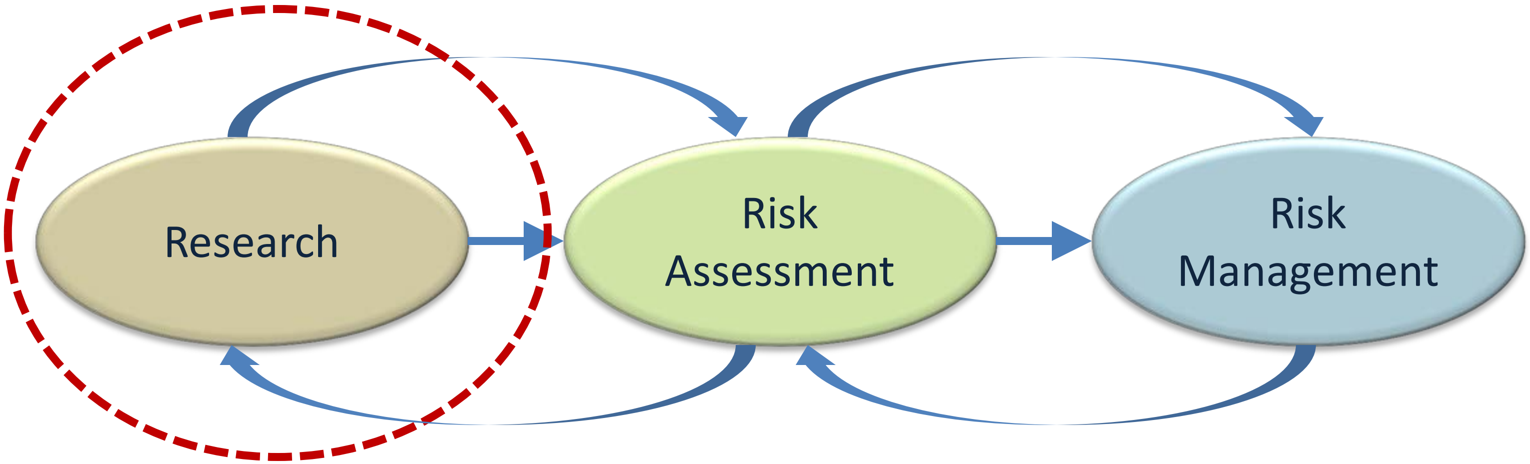
Analyzed Round 3 Scores

Ratings analyzed and reported during the workshop represent final prioritization.
Participants form break-out groups for top areas and refine research questions to prioritize element-influential factor pairs

Holistic Thinking

Detailed Thinking

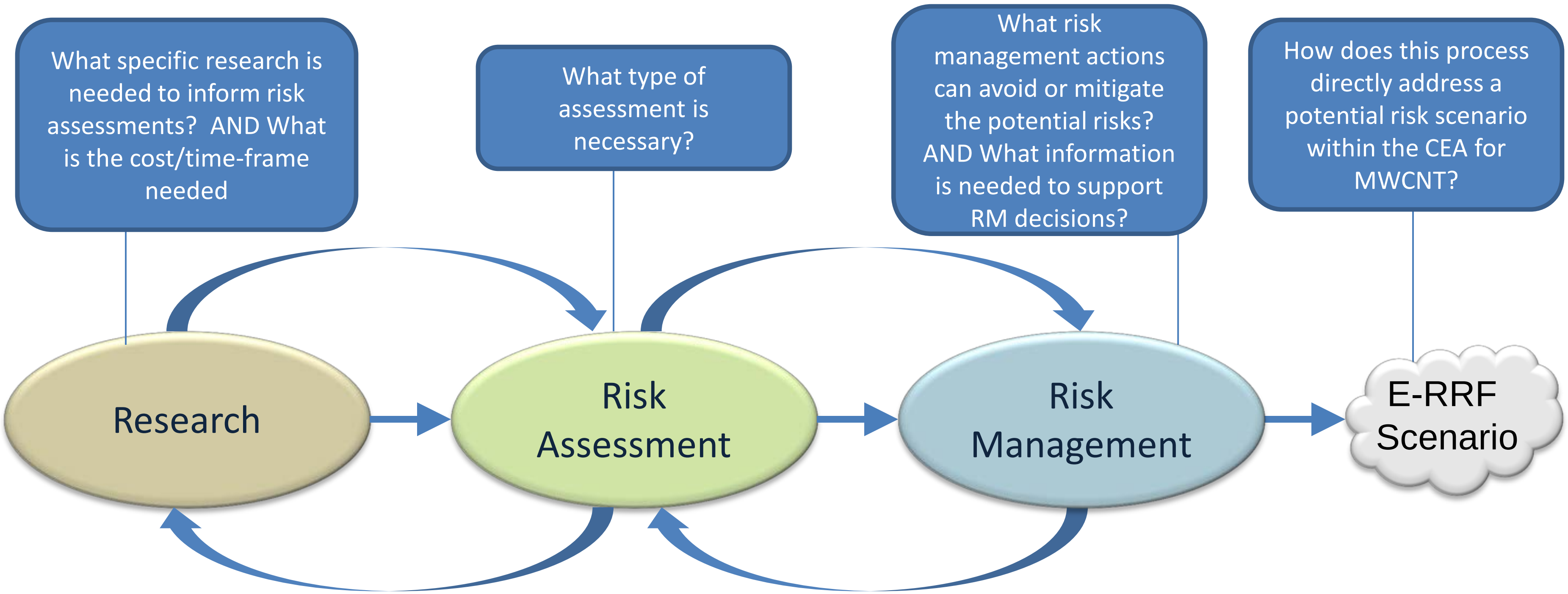
Your Role in the CEA Process: Research Gap Identification & Prioritization



- ***Group Purpose:*** Collectively identify & prioritize research gaps to support assessments that inform risk management decisions

- We are not asking you to be risk assessors
- We are asking for your judgment on:
  - What information do you think you need to know to understand, and therefore manage, the most significant risks associated with MWCNT?
  - What is the current state of knowledge about that information?

Your Goal in the CEA Process: Building the context for the research you recommend

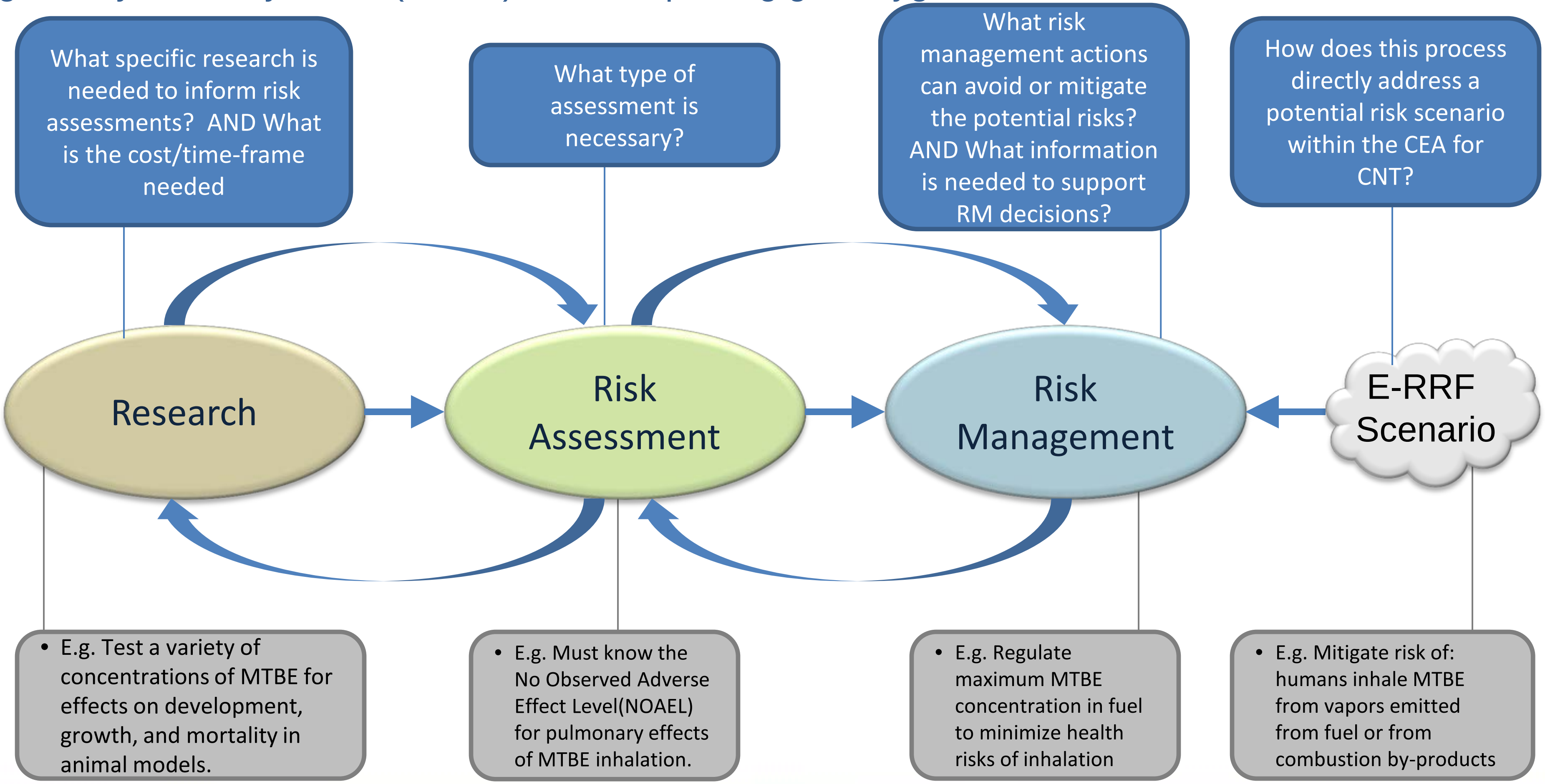


Q: Great idea – how do we make this specific and actionable?
A: Good question –

1. Link to our prioritized E-RRF pairs.
2. Work backwards from risk scenarios related to E-RRF pairs.

Your Goal in the CEA Process: Building the context for the research you recommend

e.g. Methyl tert-butyl ether (MTBE) – lead-replacing gas oxygenate



Your Goal in the CEA Process:
Building the context for the research you recommend

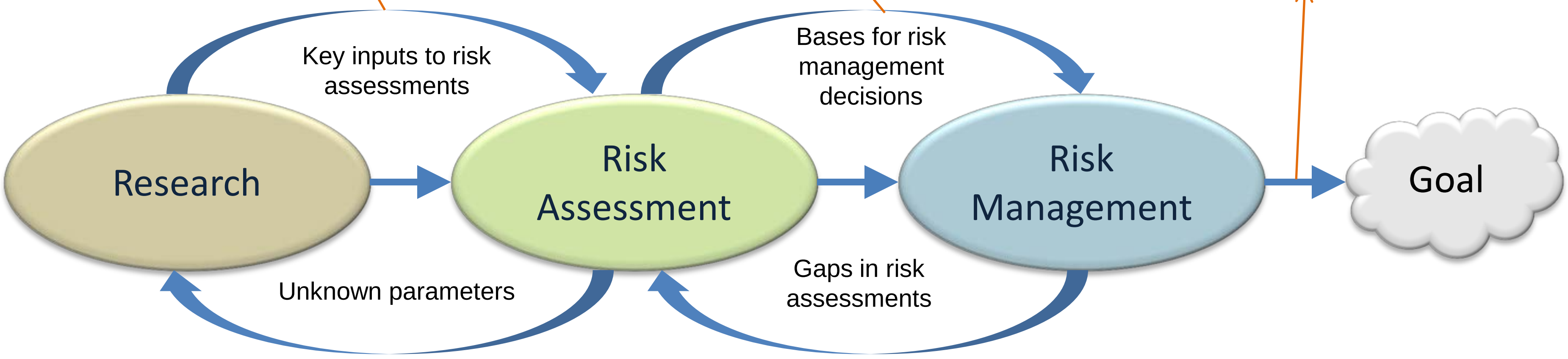
Key inputs to enable risk ass
- Critical concentrations of su induce biological effects
- Exposure quantities
- Knowledge of partitioning behavior

Key bases for risk management decisions, e.g.:
- Thresholds
- PMN decis
- Hazardous

Potential Risk Scenario

Risk Management Actions Can Support A Variety of Goals

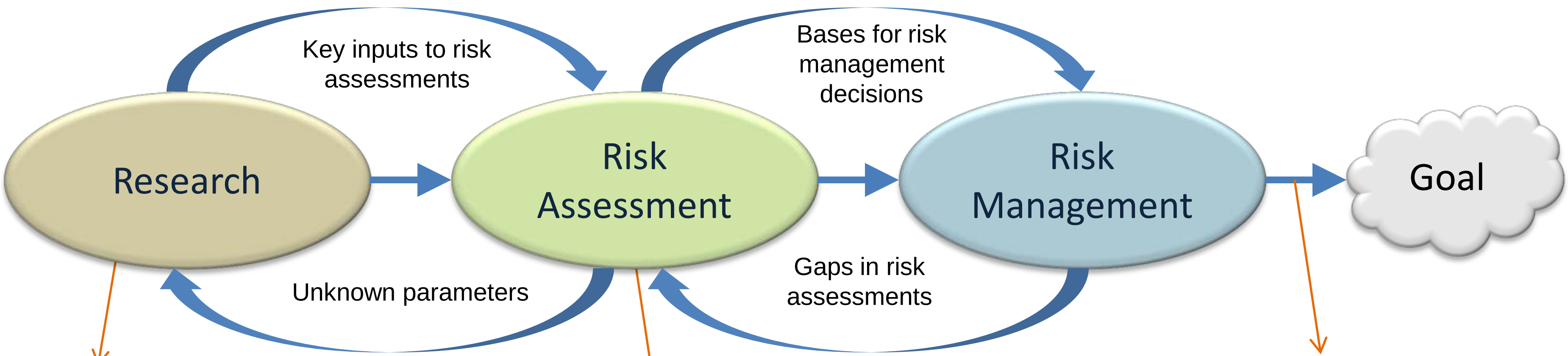
- **Risks to workers due to inhalation of MWCNTs**
- **Potential risk to ecological system health**
- **Potential releases of MWCNTs from manufacturing plants**



Your Goal in the CEA Process: Building the context for the research you recommend

Potential Risk Scenario

- **Risks to workers due to inhalation of MWCNTs**
- **Potential risk to ecological system health**
- **Potential releases of MWCNTs from manufacturing plants**



What unknowns are hampering the ability to assess these risks?

What types of assessments are missing that would inform decisions?

What types of risk management actions would mitigate the potential risk(s) in this scenario?

Moving from assessments to decisions

- Risk Assessment (health, ecological)
  - Set of procedures to estimate if a risk occurs from a substance
- Life Cycle Assessment (LCA)
  - Standardized decision-support tool to assess potential impacts throughout life cycle stages
- Others
  - Environmental Impact Assessment (EIA)
  - Comparative Risk Assessment
  - Integrated Environmental Health Impact Assessment
  - Cost/Benefit Analyses

Moving from assessments to decisions

Key Risk Assessment Concepts

Cancer Risk

- **For cancer causing substances, estimated risks are the probability of an individual developing cancer over a lifetime as a result of exposure. A common threshold selected for risk management is 10^{5} (1 in 100,000) but sometimes 10^{6} (1 in 1,000,000) is selected for residential exposures.**

Noncancer Risk

- **For noncancer effects, risk assessment results are often expressed as hazard quotients (HQs), which are the ratio of the estimated concentration to some benchmark concentration. Benchmarks may be, for example, the concentration below which no effects are observed.**

Chronic versus Acute Risk

- **In chronic exposures, the dose is delivered over a relatively extended period of time (years), possibly intermittently at low concentrations. In acute exposures, the dose is typically delivered in a single event.**

Probabilistic distributions and percentiles

- **Results of our probabilistic evaluations are distributions that capture variable conditions. Percentiles within the distribution represent the values that are greater than the specified percentage of values in the distribution. For example, 50 percent of the values are less than the 50th percentile value (which is also often called the median). The 90th percentile has often been chosen by EPA as an appropriate threshold to manage risk.**

Moving from assessments to decisions

- Risk Assessment → Risk Management: actions and decisions to reduce potential risks

- An example: Incorporation of nanoTiO_2 into Sunscreen

Potential Risk Assessment Result: Skin irritation caused by exposure to nanoTiO_2

?

Potential Risk Management Action: Adapt sunscreen warning labels to provide recommended amount and application frequency

Breakout Group Template

For each specific E-RRF pair & potential risk scenario

	What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario for this E-RRF?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?	What specific detailed research is needed to provide such information identified previously?	What is the estimated cost for completion for this research question in US$?	What is the estimated timeframe for completion of this research question in years?
	Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**	**Research**	**Estimated finances ($)**	**Estimated time frame (years)**
1							
Rationale							
2							
Rationale							
3							
Rationale							

Participants can use the rationale rows to place group discussion notes related to the rationale for each question.

Moving from assessments to decisions

Reaching a Risk Management Decision

What fundamental research is needed to assess the risk of this product?

Which scenarios pose the greatest risk?

What is an expected exposure level/dose?

When and how will exposure occur?

What are the specific effects?

How does this information get communicated to a risk manager/stakeholders?

How does the risk manager interpret the results?

What risk management action/decision best alleviates the risk?

Context matters: Where are we in the life cycle?

How do particular actions fit within gov't/company policies

Group	Participant names	E-RRF pairs
1	James Bonner David Ensor Brian O'Connor	**Human – Non-cancer** **Human: Occupational-Inhalation** **Human – metabolism** **Human – excretion**
2	Ian Illuminato John Bang Stephen Klaine Larry Kapustka	**Air – Persistence** **Air – mobility** **Human – Absorption** **Disposal/Recycling – Volume**
3	Paul Westerhoff Jessican Coleman Elijah Petersen	**Wastewater – Persistence** **Wastewater – Mobility** **Sediment – Persistence**
4	Jie Liu Bryce Marquis Debbie Lander	**Product Manufacturing – Release Rate** **Use – Release rate** **Disposal/Recycling – Release Rate** **Material Processing – Release rat**

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Workshop Output

October 31, 2012

CEA MWCNT Prioritization Tool: Analytical Results

WHO
All Participants

WHEN
June 26th, 27th → Early July → Late July → Early August → Mid August

WHAT
1. Attend Webinar
2. Receive Case Study
3. Pre-Test on Case Study Review
4. Round 1 Prioritization
5. Review Round 1 Responses
6. Round 2 Prioritization
7. Review Round 2 Responses
8. Submit Answers to Charge Questions

WHO
Sub-set of Participants with Expertise in Prioritized Research Areas

WHEN
Late August → Workshop October 29th, 30th, 31st → February 2013

WHAT
9. Invited to Workshop
10. NGT Round Robin Discussion
11. Round 3 Prioritization
12. Build Detailed Research Questions

YOU ARE HERE

Receive Access to Final Report

CEA MWCNT Prioritization Process

Nanoscale Carbon Case Study

CEA Prioritization Round 1

All participants rate the CEA Framework based on:
- Importance to risk assessment
- Confidence in data to support risk management decisions

Analyzed Round 1 Ratings

CEA Prioritization Round 2

All participants re-rate the CEA Framework based on:
- Importance to risk assessment
- Confidence in data to support risk management decisions

Analyzed Round 2 Ratings

Generation of Research Question Starter Set

All participants generate top three research questions for the prioritized areas

Analyzed Round 2 Ratings

Research Question Starter Set

Final Workshop:
- CEA Prioritization Round 3
- Generation of Final Research Questions

Experts specialized in prioritized areas use NGT to nominate priority research areas.
Participants work individually to re-rate the CEA Framework a third time

Analyzed Round 3 Scores

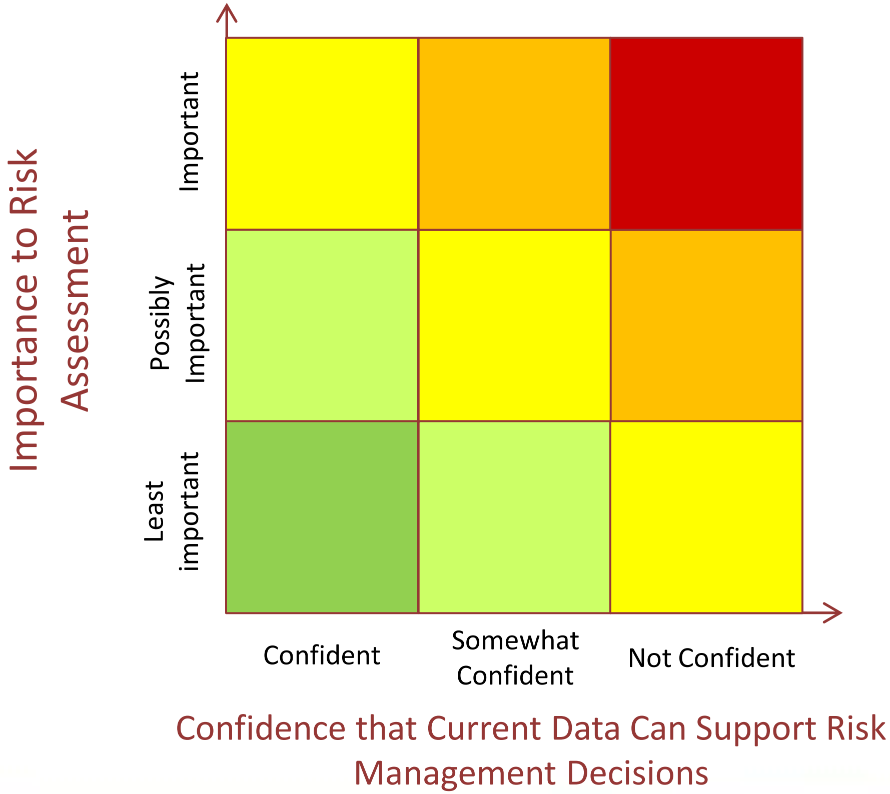
Ratings analyzed and reported during the workshop represent final prioritization.
Participants form break-out groups for top areas and refine research questions to prioritize element-influential factor pairs

Holistic Thinking

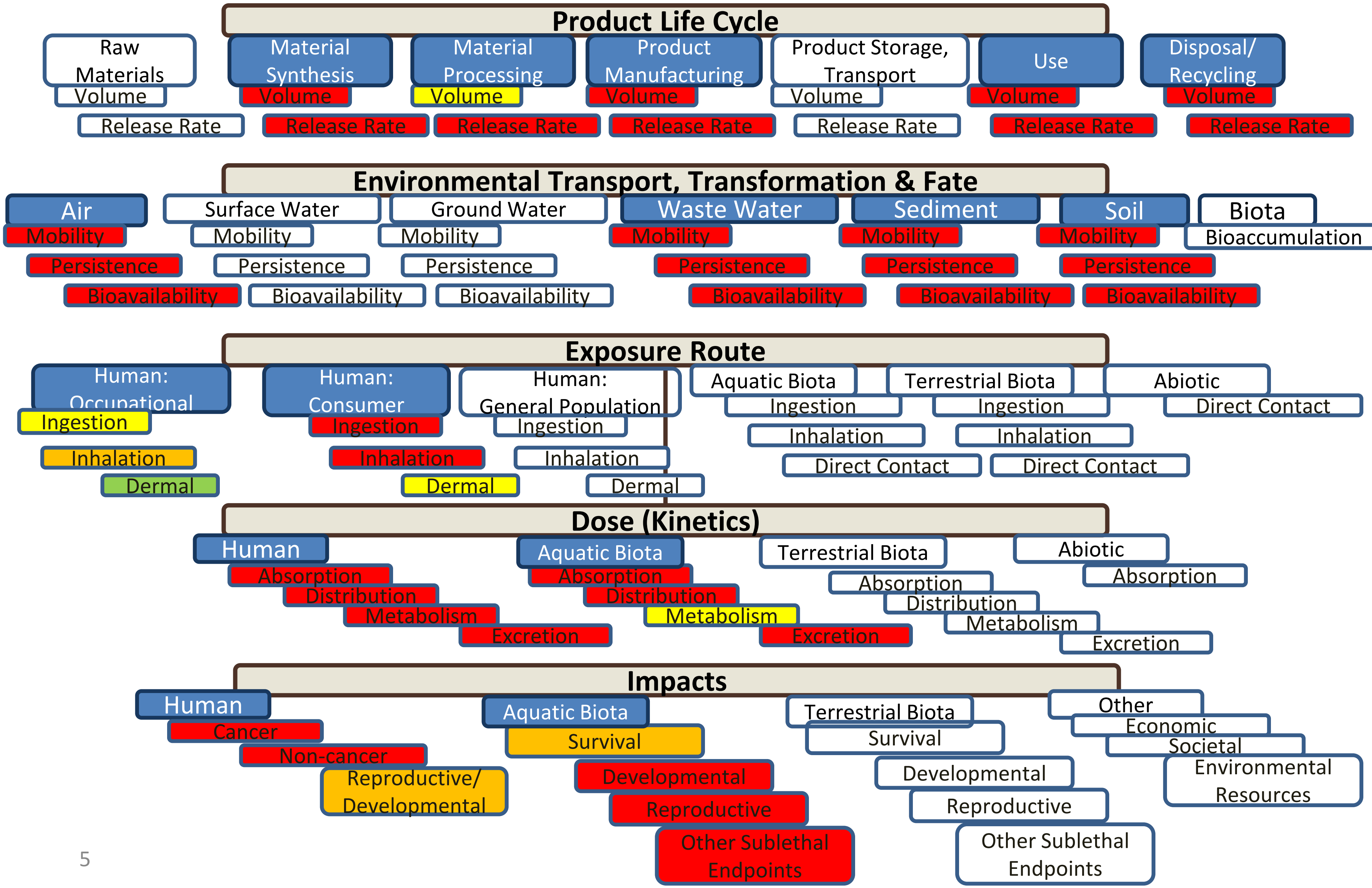
Detailed Thinking

CEA MWCNT Prioritization Tool Output

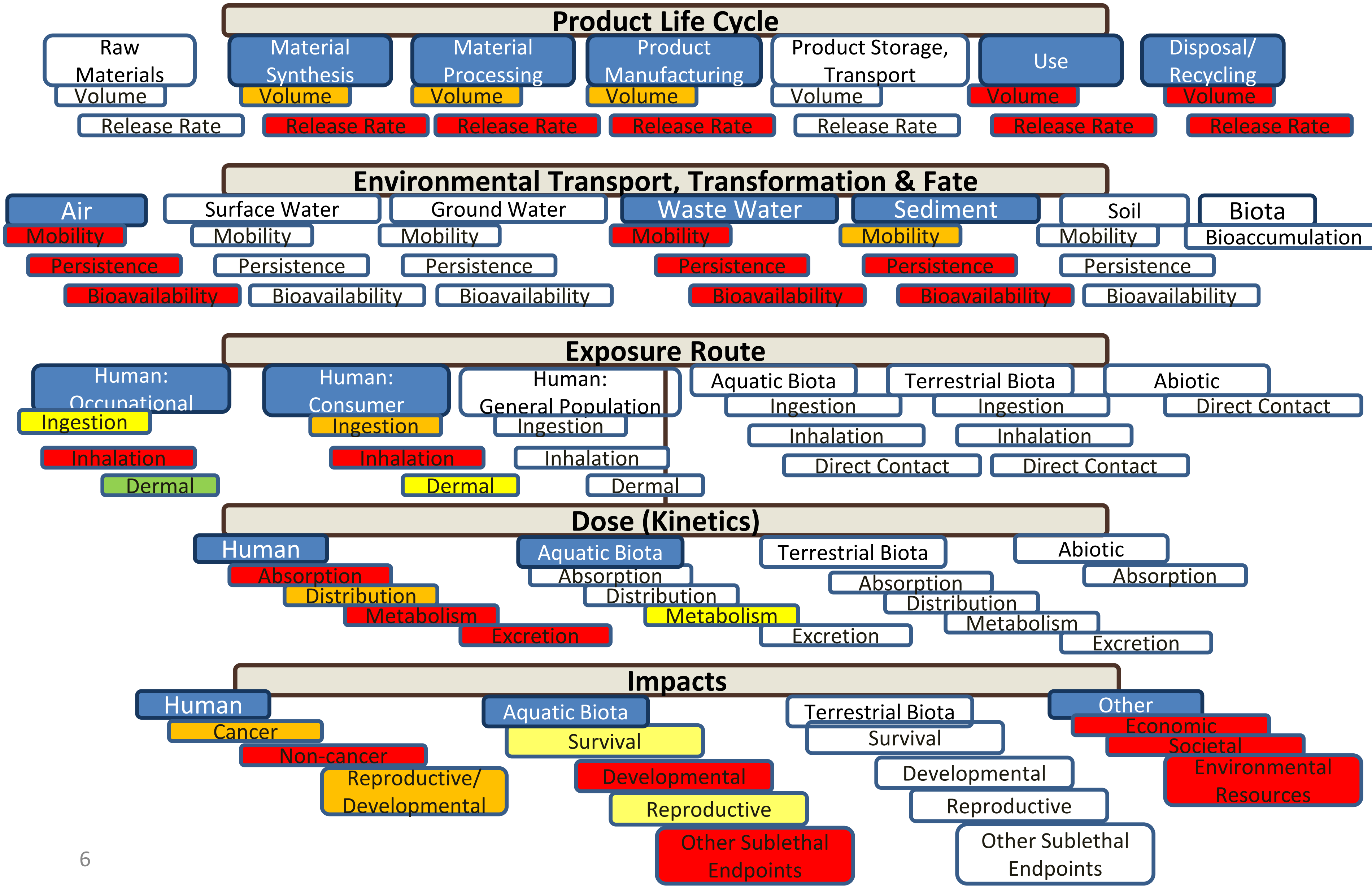
- Research areas falling into red or orange boxes of the CEA Prioritization Matrix will be elevated for development of research questions by experts during the Final Workshop (CEA Prioritization Round 3).



Results of Round 2:



Results of Round 3: Breakout Groups



Results of Round 3: Breakout Groups

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bioaccumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

Dose (Kinetics)

- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

X

Results of Round 3: "Final 15"

Product Life Cycle

- Raw Materials
  - Volume
  - Release Rate
- Material Synthesis
  - Volume
  - Release Rate
- Material Processing
  - Volume
  - Release Rate
- Product Manufacturing
  - Volume
  - Release Rate
- Product Storage, Transport
  - Volume
  - Release Rate
- Use
  - Volume
  - Release Rate
- Disposal/ Recycling
  - Volume
  - Release Rate

Environmental Transport, Transformation & Fate

- Air
  - Mobility
  - Persistence
  - Bioavailability
- Surface Water
  - Mobility
  - Persistence
  - Bioavailability
- Ground Water
  - Mobility
  - Persistence
  - Bioavailability
- Waste Water
  - Mobility
  - Persistence
  - Bioavailability
- Sediment
  - Mobility
  - Persistence
  - Bioavailability
- Soil
  - Mobility
  - Persistence
  - Bioavailability
- Biota
  - Bioaccumulation

Exposure Route

- Human: Occupational
  - Ingestion
  - Inhalation
  - Dermal
- Human: Consumer
  - Ingestion
  - Inhalation
  - Dermal
- Human: General Population
  - Ingestion
  - Inhalation
  - Dermal
- Aquatic Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Terrestrial Biota
  - Ingestion
  - Inhalation
  - Direct Contact
- Abiotic
  - Direct Contact

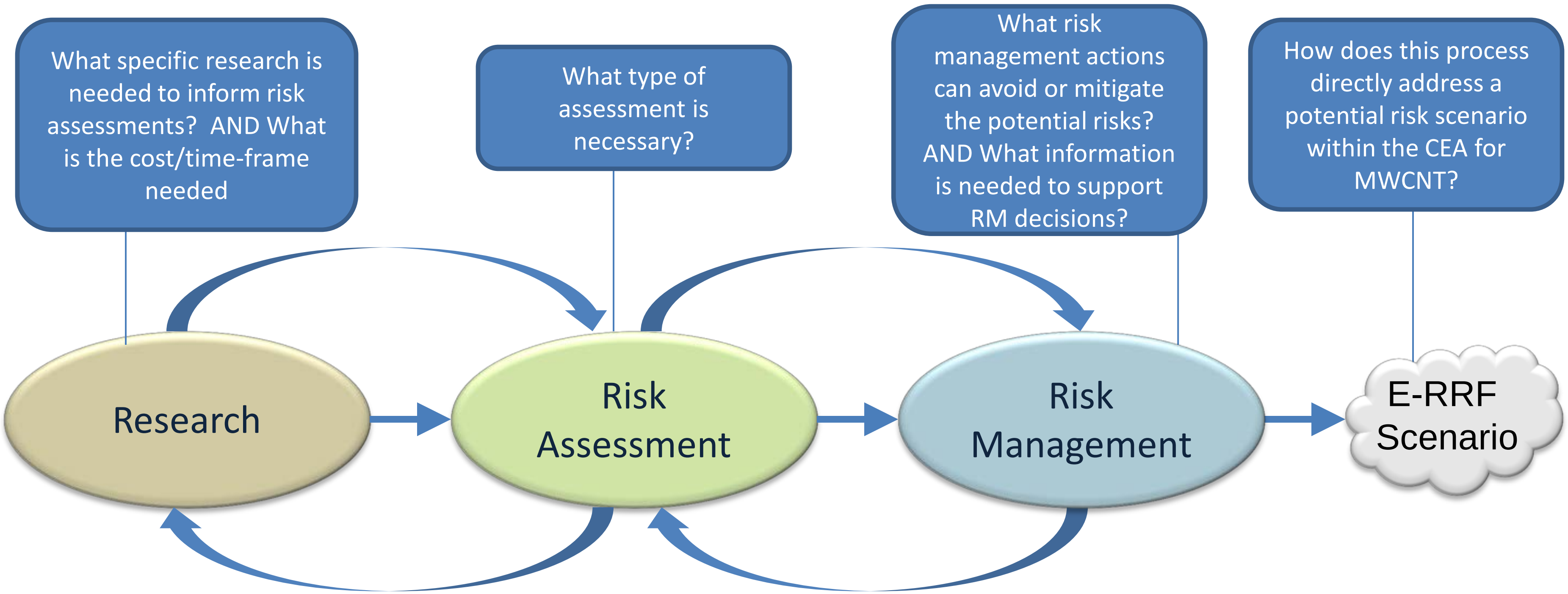
Dose (Kinetics)

- Human
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Aquatic Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Terrestrial Biota
  - Absorption
  - Distribution
  - Metabolism
  - Excretion
- Abiotic
  - Absorption

Impacts

- Human
  - Cancer
  - Non-cancer
  - Reproductive/ Developmental
- Aquatic Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Terrestrial Biota
  - Survival
  - Developmental
  - Reproductive
  - Other Sublethal Endpoints
- Other
  - Economic
  - Societal
  - Environmental Resources

Your Goal in the CEA Process: Building the context for the research you recommend



Q: Great idea – how do we make this specific and actionable?
A: Good question –

1. Link to our prioritized E-RRF pairs.
2. Work backwards from risk scenarios related to E-RRF pairs.

Group	Participant names	E-RRF pairs
1	James Bonner David Ensor Brian O'Connor	**Human – Non-cancer** **Human: Occupational-Inhalation** **Human – metabolism** **Human – excretion**
2	Ian Illuminato John Bang Stephen Klaine Larry Kapustka	**Air – Persistence** **Air – mobility** **Human – Absorption** **Disposal/Recycling – Volume**
3	Paul Westerhoff Jessican Coleman Elijah Petersen	**Wastewater – Persistence** **Wastewater – Mobility** **Sediment – Persistence**
4	Jie Liu Bryce Marquis Debbie Lander	**Product Manufacturing – Release Rate** **Use – Release rate** **Disposal/Recycling – Release Rate** **Material Processing – Release rat**

turning knowledge into practice

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Breakout Group 1

James Bonner

David Ensor

Brian O'Connor

October 31th 2012

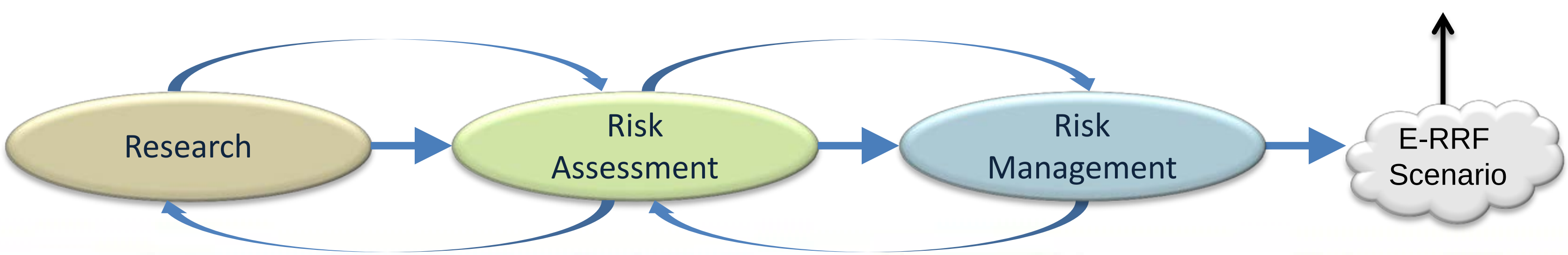
Our Breakout Group Focus

- Human: Non-cancer
- Human: Occupational – Inhalation
- Human: Metabolism
- Human: Excretion

Human: Non-cancer

Scenario

- **The MWCNT used in the upholstery application ("coated" or "functionalized") causes non-cancer effects after either acute or chronic exposures**



Human: Non-Cancer

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?

Risk Management	Informing Management	Assessment	Informing Assessment
Ban the material outright if not proven safe	Safe exposure limits for consumers or workers	NOAEL or LOAEL for the relevant material to be used in consumer or occupational exposure scenarios	Rodent toxicity data with exposure relevant material
Ban the material outright if not proven safe	Safe exposure limits for susceptible individuals	NOAEL or LOAEL for the relevant material to be used in consumer or occupational exposure scenarios for susceptible populations	Rodent toxicity data with exposure relevant material in susceptible populations

Human: Non-Cancer

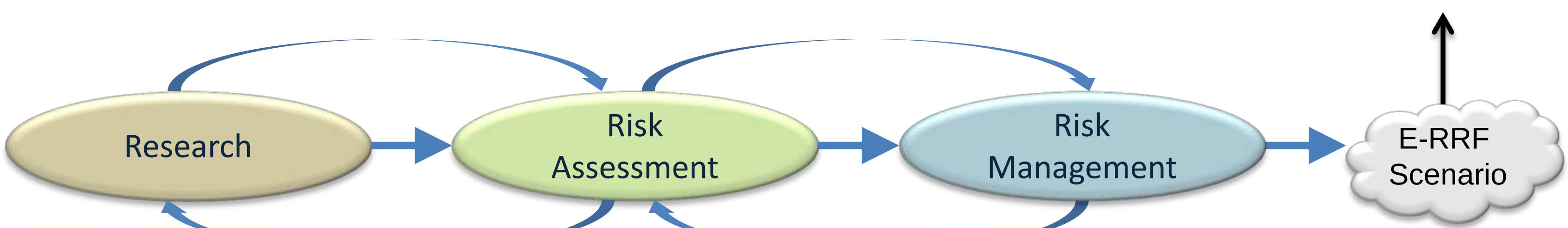
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
Conduct acute and chronic rodent bioassay studies after inhalation exposure at relevant doses using well-characterized material	$2 M for 2 year rodent bioassay including an additional year to setup and analysis	3 years
Perform experiments to test impacts of exposure on immune compromised individuals	$1M	3 years

Human: Occupational - Inhalation

Scenario

- **Workers inhale the relevant material during any part of the manufacturing process**



Human: Occupational – Inhalation

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Ban the material outright if not proven safe	Safe exposure limits for consumers or workers	NOAEL or LOAEL for the relevant material in occupational inhalation exposure scenarios	Rodent data with exposure relevant material
Engineering controls and personal protective equipment	Safe industrial exposure limits for workers	Comprehensive occupational exposure assessment	Impact of co-factors (e.g., solvents, resins) on inhalation exposure

Human: Occupational – Inhalation

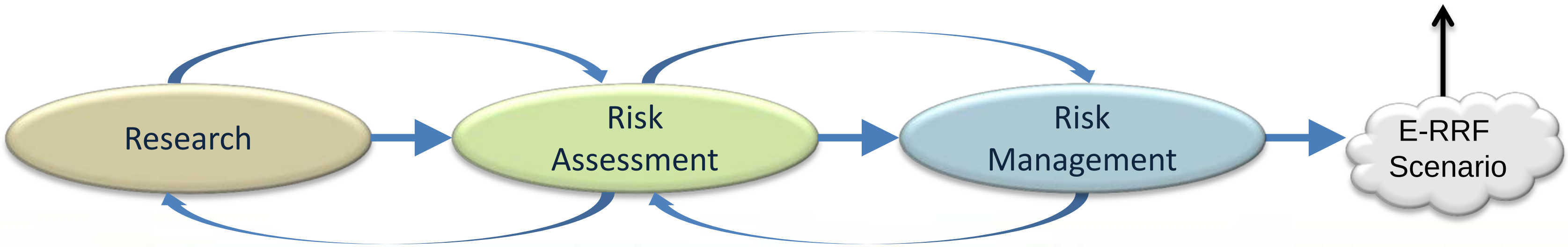
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
Acute and chronic rodent bioassay studies after inhalation exposure at relevant doses of well-characterized material	$2 M for 2 year rodent bioassay including an additional year for setup and analysis	3 years
Analytical and rodent studies to examine effect of co-factors on particles size, deposition , translocation, and removal	$2 M for 2 year rodent bioassay including an additional year to setup and analysis	3 years

Human: Metabolism

Scenario

- **The relevant MWCNT material degrades to a more or less toxic metabolite after absorption, inhalation, or ingestion**



Human: Metabolism

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Implement appropriate control technology based on risk assessment	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Degradability of the relevant MWCNT material compared to original MWCNT
Implement appropriate control technology based on risk assessment	Half-life of relevant MWCNT material in rodents	Occupational or consumer risk assessment	Degradability of the relevant MWCNT material compared to original MWCNT

Human: Metabolism

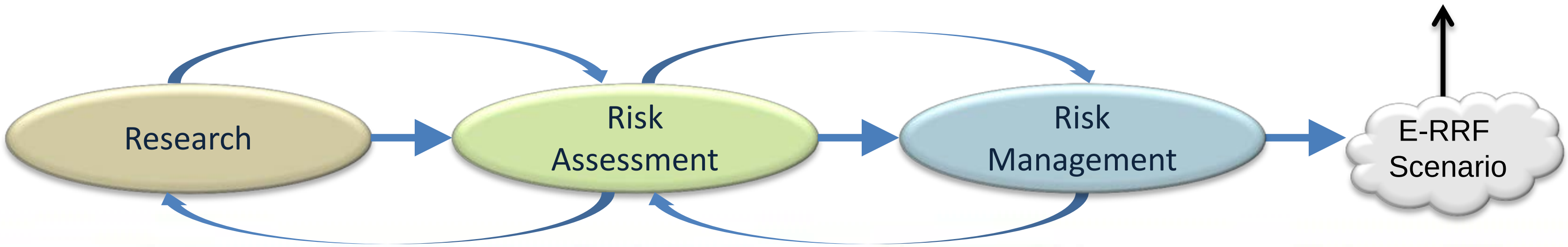
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
Develop analytical techniques for measuring the original MWCNT or metabolites in cells	$275K	2 years
Measuring the original MWCNT or metabolites in tissues after whole body inhalation exposures	$500K	2 years

Human: Excretion

Scenario

- **The relevant MWCNT material is bioaccumulated in the body after exposure and is not excreted**



Human: Excretion

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Implement appropriate control technology based on risk assessment	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Fate of relevant MWCNT material compared to original MWCNT in rodents
Implement appropriate control technology based on risk assessment	Half-life of MWCNT material in biological systems	Occupational or consumer risk assessment	Level of by-products in the body

Human: Excretion

What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
Perform experiments in rodents after exposure to determine fate and clearance of MWCNT	$500K	3 years
Develop tracer methodology to detect excretion by-products of the relevant MWCNT material	$300K	2 years

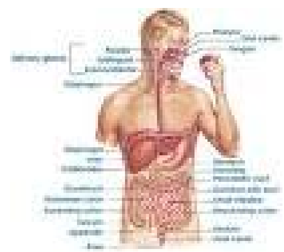
Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Breakout Group [2]

John Bang
Ian Illuminato
Larry Kapustka
Steve Klaine

Our Breakout Group Focus

- Air - Persistence

- Air - Mobility



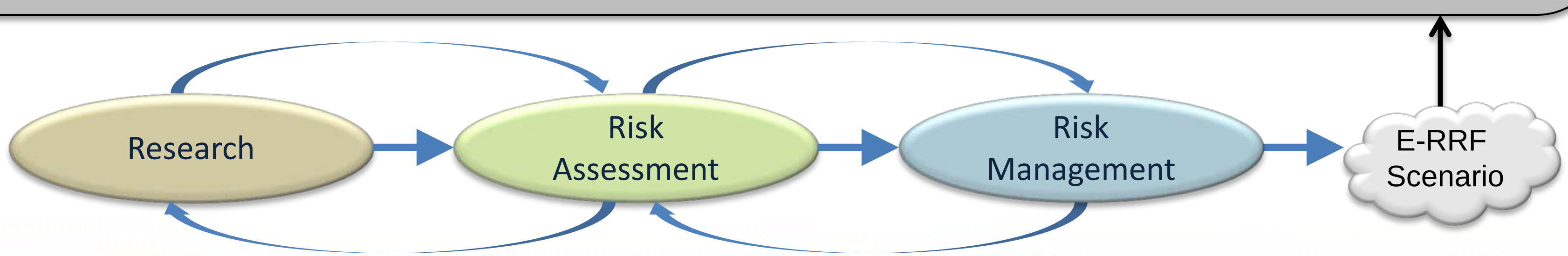
- Human - Absorption
- Disposal/Recycling – Volume

- Other - Societal

Air – Persistence

Scenario

- CNTs released into atmosphere (1) occupational (2) ambient
- Longer atmospheric residence times increase probability of exposure.



Air - Persistence

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
• Reduce atmospheric residence time • Increase propensity to aggregate • Consider moratorium on nanotube production and use.	• Measure atmospheric residence time • Determine Particle characteristics that dictate adverse health effects • Consider economic consequences of having or not having a moratorium.	• Risk assessment based on quantitative experimental data • Human Health risk assessment • Benefit/Cost Analysis	• Physical/chemical characterization of particles • Meteorological properties of atmosphere • Market analysis

Air - Persistence

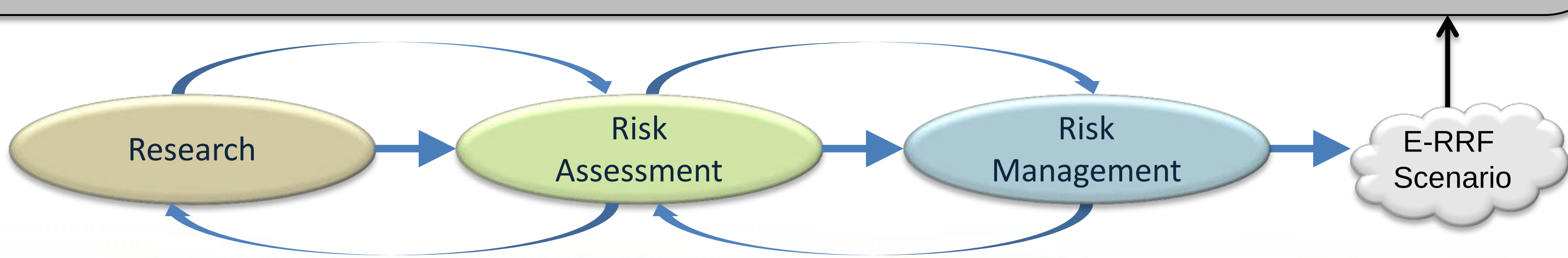
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yr)
• Develop model to predict atmospheric residence time as a function of CNT particle characteristics(QSAR).	• $500K	• 3 yr
• Determine CNT properties and meteorological properties that increase aggregation rate and decrease residence time.	• >$1 million	• 5 yr
• Develop new methods or instruments to improve CNT quantification in air (determine # or mass of CNT/m^3)	• $2 million	• 3 yr
• Apply conventional Benefit/Cost Analysis Procedures	• $200K	• 1 yr

Air - Mobility

Scenario

- CNTs released into ambient atmosphere
- Mobility dictates extent of exposure



Air - Mobility

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
• Minimize mobility • Minimize retrainment • Consider moratorium on CNT production and use	• Measure extent of atmospheric mobility • Determine Particle characteristics that dictate adverse health effects • Consider economic consequences of having or not having a moratorium.	• Risk assessment based on quantitative experimental data • Human Health risk assessment • Benefit/Cost Analysis	• Physical/chemical characterization of particles • Meteorological properties of atmosphere • Market analysis

Air - Mobility

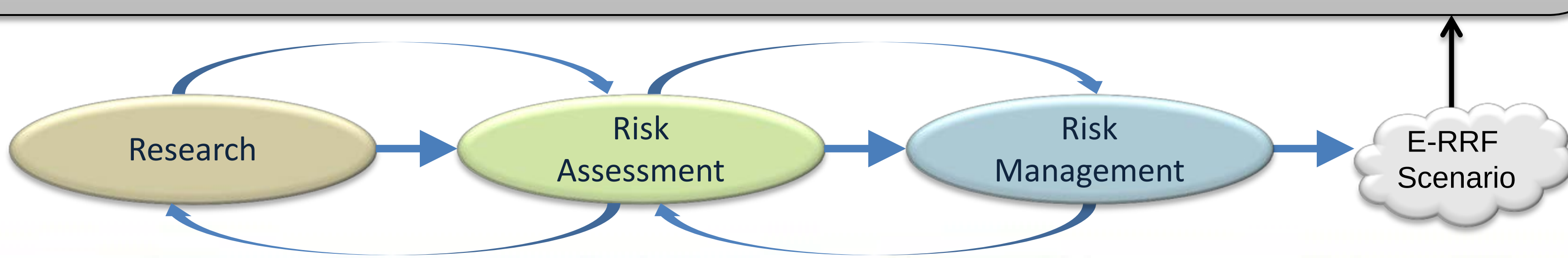
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
• Develop model to predict extent of mobility as a function of CNT particle characteristics (QSAR) for near-field and long-distance transport.	• $1 million	• 3 yr
• Alter CNT properties or meteorological properties to increase aggregation and decrease mobility	• >$1 million	• 5 yr
• Develop new methods or instruments to improve CNT quantification in air (determine # or mass of CNT/m^3)	• $2 million	• 3 yr
• Apply conventional Benefit/Cost Analysis Procedures	• $200K	• 1 yr

Human - Absorption

Scenario

- Humans are exposed via inhalation and ingestion
- Potential absorption occurs through lungs and GI tract



Human - Absorption

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
• Minimize absorption potential • Consider moratorium on CNT production and use	• Magnitude of absorption across different tissues. • Determine Particle characteristics that dictate adverse health effects • Consider economic consequences of having or not having a moratorium.	• Human health exposure assessment • Occupational exposure assessment • Benefit/Cost Analysis	• Absorption potency as a function of particle characteristics for 3 representative routes of exposure • Market analysis

Human - Absorption

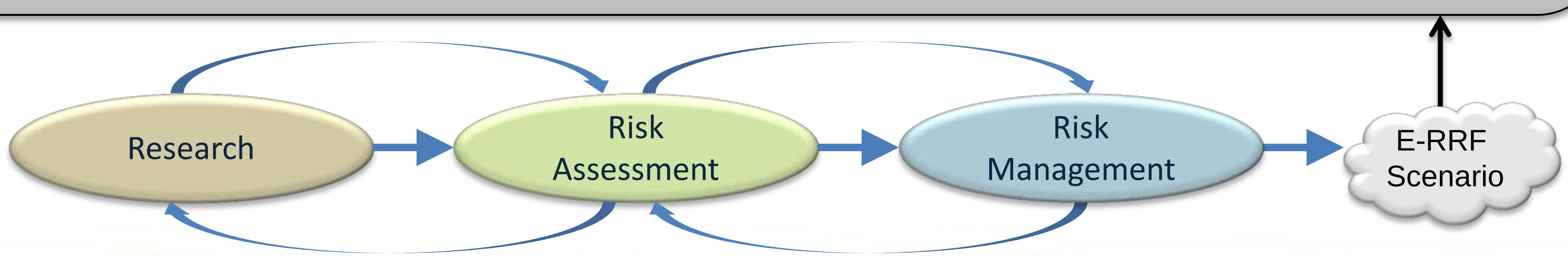
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
• Determine particle properties that influence extent and rate of absorption across mammalian lung epithelial tissue, GI luminal epithelia, and dermal layers. • Quantify extent and rate of absorption across mammalian lung epithelial tissue, GI luminal epithelia, and dermal layers. If answer is yes then: • Maximize particle properties that decrease absorption while maintaining beneficial uses.	• $5 million	• 5
• Rationale for this is that a group examining all three absorption processes is that you increase the potential for discovery of unique interactions among systems. While little evidence is available demonstrating dermal absorption (via abraded skin) further work should be considered because of the potential for high exposure especially in children.		

Disposal/Recycling - Volume

Scenario

- CNTs used as flame-retardants in upholstery
- Upholstery is used on furniture and accessories (e.g. curtains)
- End of life scenarios result in either destruction (e.g. burning), recycling, reuse, litter, or disposal in landfill.



Disposal/Recycling - Volume

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
• Reduce release through return of upholstery and upholstered products to manufacturers through reclaim system. • Consider moratorium on CNT production and use	• Quantify risk associated with aged/littered/destroyed upholstered products.	• Life Cycle Analysis • Environmental risk assessment	• Disposal volume • Reuse volume

Disposal/Recycling - Volume

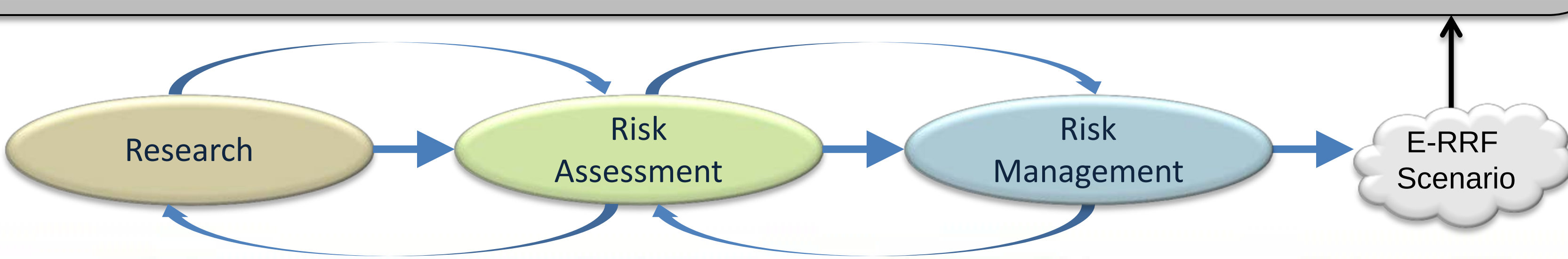
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yr)
• How much volume of CNTs are used in upholstery? • How much volume of CNTs is lost from upholstery during life span? • How much volume of CNTs is lost via destruction (e.g. burning), recycling, reuse, litter, or disposal in landfill.	• $100K	• 1 yr

Other - Societal

Scenario

- CNTs used as flame-retardants in upholstery
- Unintended consequences arise
- Government and industry becomes concerned
- Public becomes fearful
- Future, more promising applications of CNTs are abandoned



Other - Societal

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
• Build capacity and enable informed consent • Consider moratorium on CNT production and use	• Characterize capacity of stakeholders and the information flow. • Understand transparency of the information flow.	• Socioeconomic Assessment	• Public's knowledge and perception on emerging technology • Effectiveness of communication channels among industry, government, academia, NGO's, and public

Other - Societal

What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yr)
• Evaluate the capacity of the institutions to meaningfully engage the public on nanotechnology. • Characterize the public's understanding of the befits and risks of nanotechnology and their potential for participating in decision-making.	• $50K • $150K	• 0.5 yr • 1.5 yr
• Rationale is that this is an underappreciated aspect of promoting economic development and environmental protection in the midst of technological change.		
• Capacity building to improve understanding of benefits and risks of nanotechnology. • Development of a more effective systems approach to examine interrelated consequences (good and bad) of new technologies. • Development of new methods of facilitating communication amongst stakeholders on complex issues like nanotechnology	• $500K	• 2 yr

turning knowledge into practice

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Breakout Group [C]

Paul Westerhoff

Jessica Coleman

Elijah Petersen

October 31th 2012

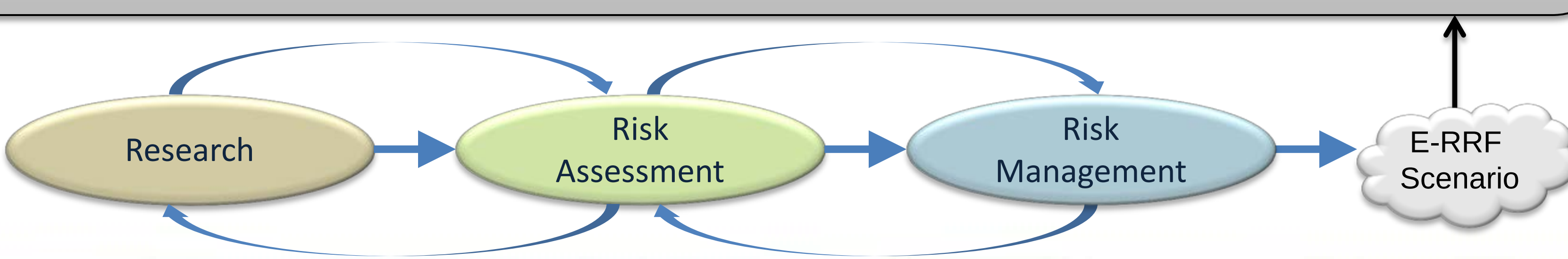
Our Breakout Group Focus

- Wastewater-Persistence
- Wastewater-Mobility
- Sediment-Persistence

Wastewaster-Persistence

Scenario

- MWCNTs are released as either pulse industrial discharges to sewers or semi-continuous loading from industrial/commercial/residential washwater exposed to flame retardant materials.



Wastewaster-Persistence

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?

Risk Management	Informing Management	Assessment	Informing Assessment
1.Regulate efficiencies of control technology that would release MWCNTs in the environment. 2. Same as 1	1. Will wastewater processes (activated sludge, disinfection processes) transform carbon nanotubes 2. Tracking of MWCNT throughout the life cycle (analogous to decaBDE congeners)	1. Laboratory experiments 2. Method development under control technology operating conditions.	1. The rate of transformation of MWCNT alone and combined in a matrix. 2. Research enables assessment of mobility of assessment within treatment plant

Wastewaster-Persistence

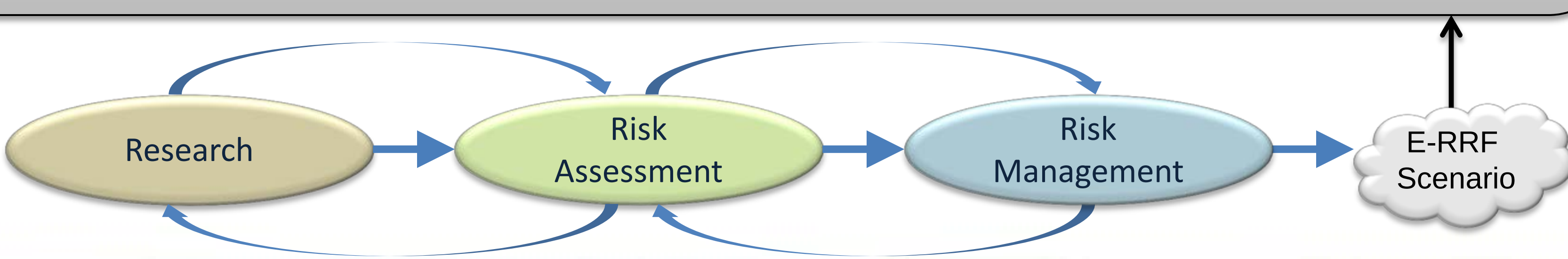
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
1. How does the degree of functionalization and changes in wastewater treatment processes affect the rate of transformation?	$400,000	3 years
2. How to extract and characterize MWCNT from suspended and fixed biomass or treated effluent with minimal modifications to surface group, functionalization, impregnated metals, and coatings	$400,000	3 years
3. What are the transformation byproducts from MWCNT and flame resistant fibers?	$300,000	3 years

Wastewater-Mobility

Scenario

- MWCNTs are released as either pulse industrial discharges to sewers or semi-continuous loading from industrial/commercial/residential washwater exposed to flame retardant materials.



Wastewater-Mobility

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?

Risk Management	Informing Management	Assessment	Informing Assessment
1. Possible pretreatment controls by industry to prevent discharge of MWCNTs. 2. Possible pretreatment controls by industry to prevent discharge of MWCNTs.	1. Pilot plant, batch experiments and modeling would predict MWCNT removal efficiency and actual MWCNT concentrations in treated effluent and biosolids. 2. Analytical techniques are required to monitor compliance, or evaluate removal in industry testing prior to approval	1. Batch or OECD experiments Would be beneficial to have pilot tests with 2 or more MWCNT materials. 2. Analytical chemistry method development	1. Distribution coefficients for some nanomaterials are available which could be used with existing WWTP models to crudely predict MWCNT removals. 2. Detection limits of several methods exist, and may be relevant to apply given current acute toxicity test results

Wastewater-Mobility

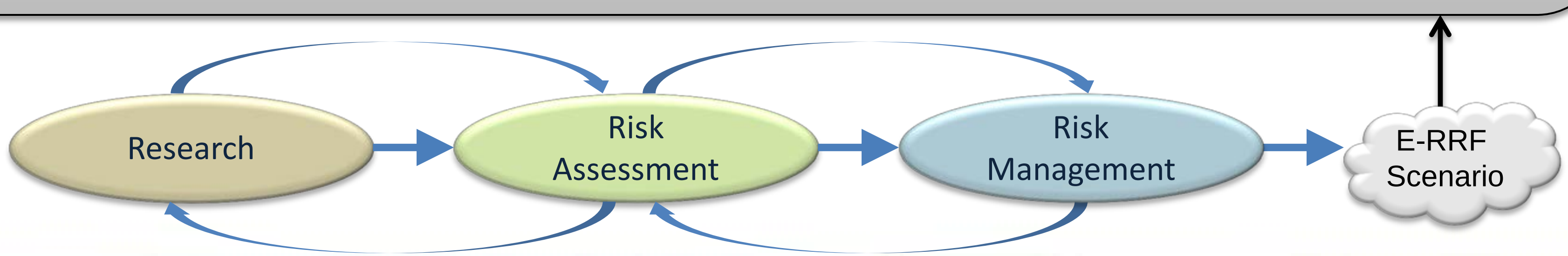
What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
1. To what extent does MWCNT surface properties and incorporation into fibers affect distribution of MWCNTs between treated effluent and biosolids for different wastewater treatment plant configurations.	$250k ($600K with pilot plant)	2.5 years (4 years with pilot)
2. Develop extraction and/or analytical techniques to quantify MWCNTs, of diverse origin , at environmentally relevant levels in raw sewage, treated effluent and biosolids.	$300k ($600k)	3 years (4 years for completely new methods)
• X	• X	• X

Sediment-Persistence

Scenario

- Continuous deposition and burial of fiber/polymers containing MWCNT and sediments from multiple sources (air, waste water discharge, release from whole products; hotspot with diffuse and continuous sediment, storm water)



Sediment-Persistence

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
1. Regulate efficiencies of control technology that would release MWCNTs in the environment. 2. Same as 1 3. Same as 1 and also including loadings of CNTs in fabrics	1. Is there long term persistence? Are MWCNT released from fabrics and sediments? 2. Tracking of MWCNT throughout the life cycle 3. What byproducts could be formed during degradation processes and would this be impacted by the MWCNT concentration in the fabrics?	1. Laboratory experiments 2. Method development under environmentally relevant conditions. 3. Laboratory experiments.	1. There are two rates of release, rate of release from a fibers and transformation of MWCNT alone and combined in a matrix. 2. Research enables changes over time in assessment of mobility, persistence and bioavailability as CNTs transform in sediment. 3. Research enables assessment about byproduct formation which may be toxic.

Sediment-Persistence

What specific detailed research is needed to provide this information?

Research	Estimated Cost (US$)	Estimated Timeframe (Yrs)
1. How does the degree of functionalization/changes in sediment affect the rate of transformation.	$300,000 for 3 $600,000 for 5	3 years initially, then 5 years
2. How to extract and characterize MWCNT from sediment with minimal modifications to surface group, functionalization, impregnated metals, and coatings	$400,000	3 years
3. What are the transformation byproducts from MWCNT and flame resistant fibers?	• X	• X

Comprehensive Environmental Assessment Applied to Multiwalled Carbon Nanotubes: Breakout Group [4]

[Jie Liu]

[Bryce Marquis]

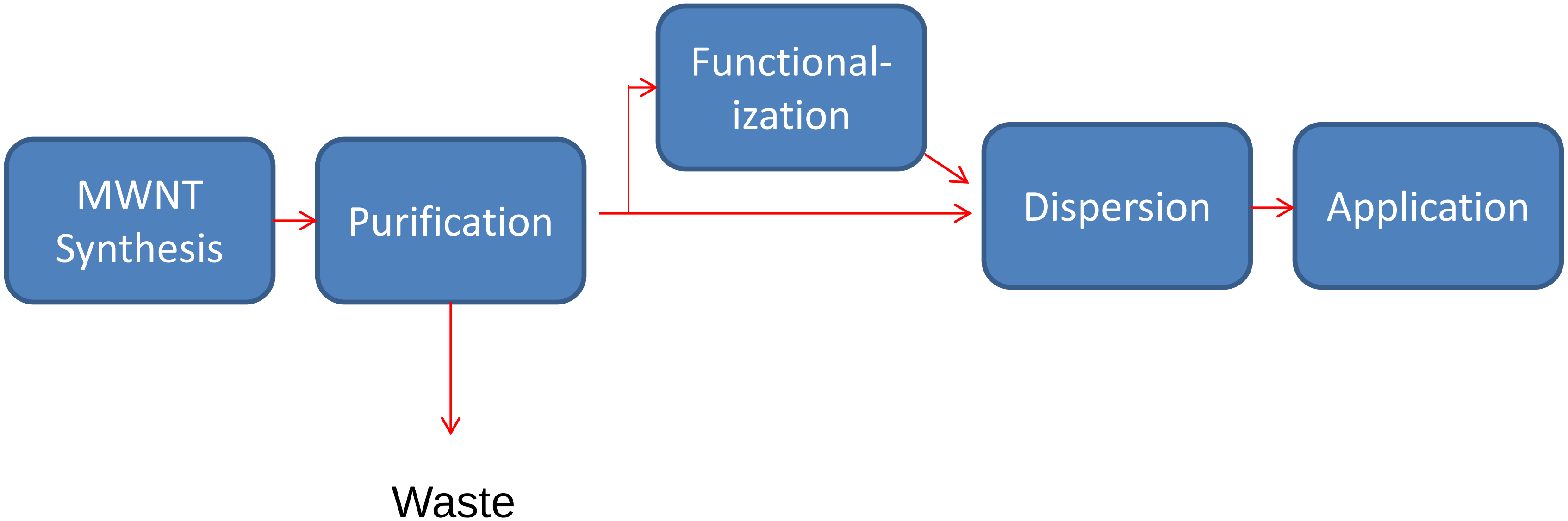
[Debbie Lander]

October 31th 2012

Our Breakout Group Focus

- Material Processing- Release rate
- Product manufacturing- Release rate
- Product use- Release rate
- Disposal-Recycle- Release rate

Manufacturing Release



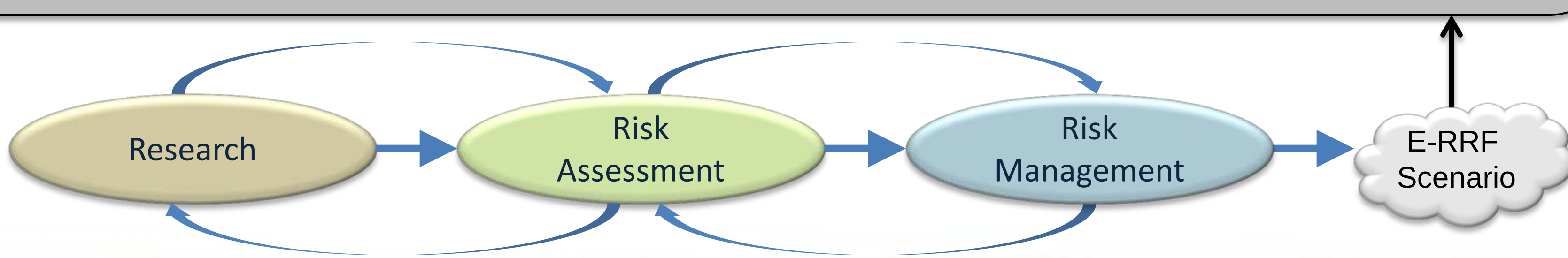
Opportunities throughout:

1) **Cleaning (liquid waste)**
2) **Transferring (occupational hazard)**

Material Processing- Release Rate

Scenario

- MWCNT are released to STP resulting in exposure to environment
- MWCNT are released to air resulting in exposure to workers



Material Processing- Release Rate

[Brief scenario tagline]

What risk management actions or decisions could avoid or mitigate the potential risks posed in	What information would you need from an assessment to support these Risk Management	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Control concentration in waste water	Help select necessary control technologies	a) Assess release rates at manufacturing facilities b) Evaluate release rates of different technologies (1) synthetic techniques (2) Filtration technologies (3) Remediation	Release rate to STP
Control occupational exposure in indoor air	Help select control measures or PPE	a) Evaluate exposure to workers at manufacturing facilities identifying key steps in exposure b) Evaluate control/PPE measures for reducing exposure	Release to indoor air

Material Processing- Release Rate [Brief scenario tagline]

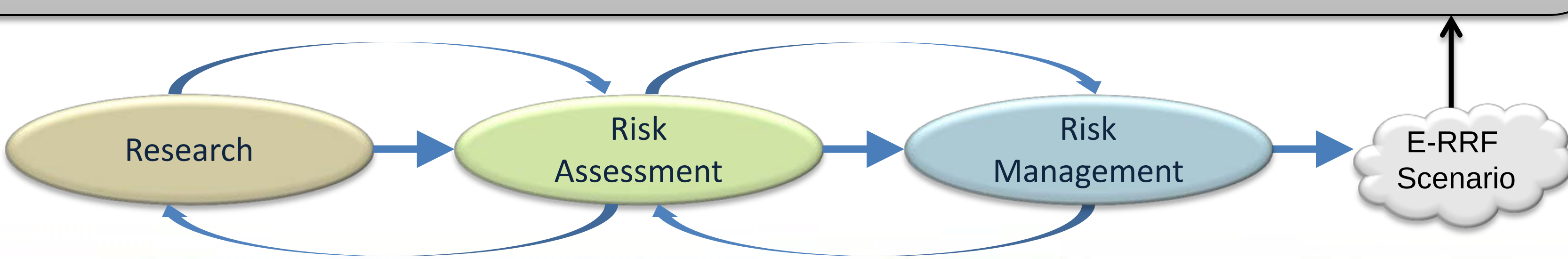
What specific detailed research is needed to provide this information?

Research	Estimated finances ($)	Estimated time frame (years)
What is occupational exposure at current MWCNT processing facilities?	100,000	1 yr
What is release rate in wastewater from current MWCNT processing facilities?	100,000	1 yr
Develop Method (instrument) to characterize and quantify in waste liquid for monitoring.	500,000	5 yrs
What is the best method to capture/destroy CNT in waste liquid?	300,000	3 yrs
Can CNT synthesis technique reduce potential releases through control of initial raw CNT form?	300,000	3 yrs
What air handling technologies can be used to reduce occupational exposure?	200,000	2 yrs

Product manufacturing- Release rate

Scenario

- MWCNT are released to STP resulting in exposure to environment
- MWCNT are released to air resulting in exposure to workers



Product manufacturing- Release rate

What risk management actions or decisions could avoid or mitigate the	What information would you need from an assessment to support	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Control concentrations of in waste water	Suggest manufacturing technologies and/or control technologies	Evaluate potential release rates depending on manufacturing technique: a) Functionalization b) Dispersion c) Coating techniques	Release rate to STP (eg, g/day) based on manufacturing technique. Effect of manufacturing technique on released particle characteristics.
Control occupational exposure	Suggest control measures or PPE	Evaluate potential occupational exposures rates depending on manufacturing technique. a) Functionalization b) Dispersion c) Coating techniques	Release rate (eg. Mass/m^3, surface area / m^3, number/m^3) to occupations air. Effect of manufacturing technique on released particle characteristics.

Product manufacturing- Release rate

[Brief scenario tagline]

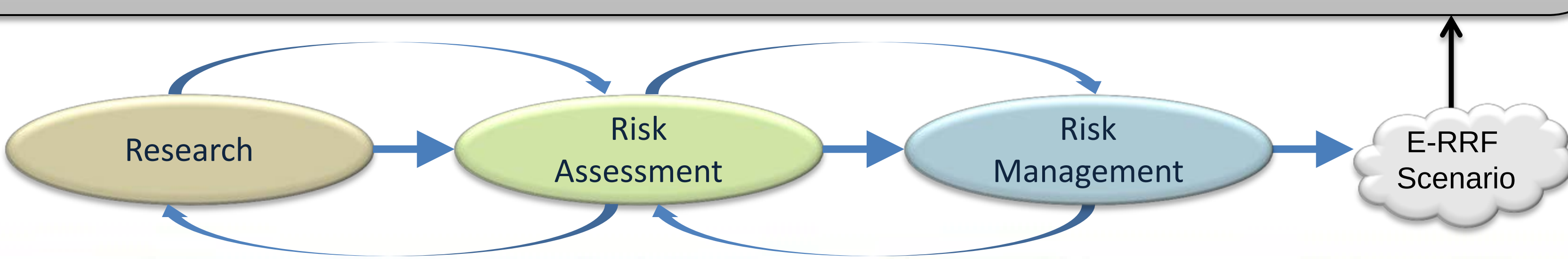
What specific detailed research is needed to provide this information?

Research	Estimated finances ($)	Estimated time frame (years)
What is the step in manufacturing that presents most risk of release to the environment?	$100,000	1 yr
What is the step in manufacturing that presents most risk of occupational exposure?	$100,000	1 year
How does MWNT functionalization affect the filtration efficiency and size distribution?	$100,000	2 yrs
How does the dispersion technique affect the filtration efficiency and size distribution?	$100,000	2 yrs

Product use- Release rate

Scenario

•MWCNT are released resulting in exposure to consumers via indoor air or the environment (via wastewater treatment)



Product use- Release rate

[Brief scenario tagline]

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Regulation of acceptable matrices for use with MWNT flame retardants.	Concentration in indoor air	Consumer health assessment including sensitive populations (children)	Effect of matrix on particle release
Regulation of acceptable matrices for use with MWNT flame retardants.	Quantify Releases to environment	Environmental assessment	Effect of matrix on particle release

Product use- Release rate

[Brief scenario tagline]

What specific detailed research is needed to provide this information?

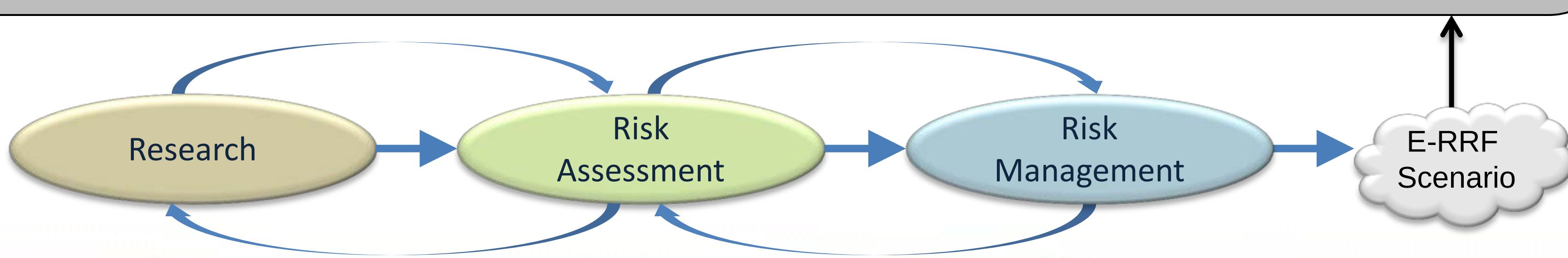
Research	Estimated finances ($)	Estimated time frame (years)
How does particle functionaliztion and matrix affect aging and release to air (use accelerated weathering test), measure quantify (number and concentration) and characterize (size distribution)?	~300,000	2-3yrs
How does particle functionaliztion and matrix affect release in washing product (use mini washing machines, measure quantify (number and concentration) and characterize (size distribution)?	~300,000	2-3 yrs

Disposal-Recycle- Release rate

Scenario

•MCNT are released during recycling for reuse (eg industrial shredding)resulting in release to environment (release to waste water) resulting in exposure to environment and release to air resulting in exposure to workers

•MCNT are released during sludge application to land either to surface biota or humans.



Disposal-Recycle- Release rate

What risk management actions or decisions could avoid or mitigate the potential risks posed in this scenario?	What information would you need from an assessment to support these Risk Management Decisions?	What type of assessment could provide this necessary information?	What information would enable this assessment but is currently unavailable?
Risk Management	**Informing Management**	**Assessment**	**Informing Assessment**
Control occupational exposure for workers in recycling facilities.	Help select control technologies or PPE	Occupational assessment	Release rates to air from shredding
Regulate disposal of sludge waste.	Release potential from different sludge processing.	Environmental assessment (eg is there enough sludge going to land that uptake from plants, or exposure to farmers)	Volume applied to land/yr (since the release is complete to land with sludge)

Disposal-Recycle- Release Rate

What specific detailed research is needed to provide this information?

Research	Estimated finances ($)	Estimated time frame (years)
What is the airborne release rate of MWCNTS Study during shredding (eg. form, size distribution, number & mass concentration)?	100,000	1 yr
Survey of nano industry and municipal STP to gather mass of sludge/yr applied to land	50,000	1 yr