1.0 INTRODUCTION

1.1 BACKGROUND

Mercury is a naturally occurring element that is neither created nor destroyed. It enters the environment as a result of natural (*e.g.,* volcanos, fires, surface emissions) and human (*e.g.,* combustion, commercial products) activities (i.e. anthropogenic sources). Depending on the situation, once deposited on land or water mercury can re-enter the atmosphere. Mercury is found in the environment as an inorganic (*e.g.,* elemental mercury vapor [Hg^0], gas-phase ionic mercury [Hg^{+2}], particulate-bound mercury [Hg_p]), and in organic forms (*e.g.,* methylmercury). It is emitted from human activities in the inorganic form[1]. Over the years, some mercury compounds have been specifically developed as pesticides, fungicides, and germicides to be used on grains, in paints, and with vaccines.

> The amount of mercury released into the biosphere has increased since the beginning of the industrial age. Mercury in the atmosphere can be transported thousands of miles from sources of emission and can circulate in the atmosphere for up to a year. Most of the mercury in water, soil, sediments, or plants and animals is in the form of inorganic mercury salts and organic mercury (e.g., methylmercury). The inorganic form of mercury, when either bound to airborne particles or in a gaseous form, is readily removed from the atmosphere by precipitation and is also dry deposited. As it cycles among the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood.
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> Excerpt from the Executive Summary of the *Mercury Study Report to Congress*, Volume 1, December 1997 (EPA, 1997a).

Mercury and its compounds are persistent, bioaccumulative and toxic, and they pose human and ecosystem risks. The intentional use of mercury in products (*e.g.,* batteries, paints) has decreased significantly in the past twenty years (Sznopoek and Goonan, 2000). Since the 19th Century, however, the total amount of mercury in the environment has increased by a factor of two to five above pre-industrial levels (Mason, et. al, 1994). As the quantity of available mercury in the environment has increased, so too have the risks of neurological and reproductive problems for humans and wildlife. This makes mercury a pollutant of increasing environmental concern in the United States, and throughout the world.

The 1997 *Mercury Study Report to Congress* improved EPA's understanding of mercury and its impacts. The Agency prepared the *Mercury Study Report to Congress* in response to Title III, section 112 (n)(1)(B) of the Clean Air Act Amendments (CAA) of 1990 (U.S. Congress, 1990). In that legislation, Congress directed EPA's Administrator to conduct ". . . a study of mercury emissions from electric utility steam generating units, municipal waste combustion units, and other sources, including area sources." As part of the study, the Agency was asked to consider mercury emissions: (1) rate and mass, (2) health and environmental effects, and (3) control technologies, including the costs of such technologies. In carrying out the study, EPA modeled the emissions of major anthropogenic sources in the United States and concluded that there was ". . . a plausible link between anthropogenic releases[2] of mercury from industrial and combustion sources in the United States and methylmercury in fish"(EPA, 1997a). The *Mercury Study Report to Congress* also concluded that the fish ingestion exposure pathway was the route of greatest interest for stack-emitted mercury. As part of the report, EPA conducted a quantitative human health risk assessment of methylmercury based on fish consumption surveys. This risk assessment estimated that between one and three percent of women of childbearing age (i.e. between the ages of 15 and 44 years) eat sufficient amounts of fish for their fetuses to be at risk from methylmercury exposure.

In addition to the *Mercury Study Report to Congress*, a number of other EPA documents have demonstrated the need for the *Mercury Research Strategy*. For example, the *Clean Water Action Plan* (EPA, 1998a) includes a goal to improve assurance that fish and shellfish are safe to eat, and specifically calls for action on mercury. The *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units - Final Report to Congress* (EPA, 1998b) identifies hazardous air pollutant emissions from utility boilers. The report indicates that of the pollutants studied, on balance, mercury releases from coal-fired power plants are the greatest potential public health concern. The *Deposition of Air Pollutants to the Great Waters: Third Report to Congress* (EPA, 2000a) lists mercury among the 15 Great Waters "Pollutants of Concern." Finally, the EPA Program Offices and Regions, via the Mercury Task Force (MTF), have prepared the *Draft EPA Action Plan for Mercury* as part of A *Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic Pollutants* (Federal Register, 1998). A final plan, which includes a number of near-term and longer-term regulatory and voluntary actions that EPA will undertake to address mercury, is expected in late-2000.

ORD developed the *Mercury Research Strategy* in close consultation with EPA's Program and Regional Offices and will use it to guide the development of a more detailed multi-year implementation plan in FY 2001. The *MRS*

provides strategic guidance for ORD's mercury research program over the next five years (FY2001 - 2005). It is specifically designed to target both near-term and long-term scientific research needs. In the near term, ORD plans to focus on combustion risk management. In the longer term, ORD will emphasize research that enhances the fundamental understanding of human health effects and exposure, ecological effects and exposure, non-combustion risk management, and risk communication. Mercury fate and transport research will be a focus throughout the five-year time frame of the *MRS*. The *Mercury Research Strategy* recognizes the global nature of the mercury problem and the need for addressing impacts in the United States via hemispheric transport of emissions generated by other nations. Its emphasis, however, is on domestic sources. This is in accordance with existing EPA program priorities, although priorities can change as a result of changing Agency needs.

The goal of the *MRS* will be accomplished through an applied in-house research program conducted by ORD laboratories and assessment center. Coupled with these in-house efforts, ORD's Science to Achieve Results (STAR) Grants Program conducted by the National Center for Environmental Research (NCER) will sponsor extramural research. This research will advance the fundamental understanding of important mercury and methylmercury issues. Other organizations will also be invited to address pertinent scientific and technical topics in their areas of competency. The research conducted under the *MRS* will be multi-disciplinary in nature, requiring engagement and collaboration across a host of different scientific and technical disciplines. Results from the mercury research program will provide the scientific underpinnings for any actions (*e.g.*, voluntary, regulatory) that the Agency chooses to pursue in the future to address mercury risks.

1.1.1 Exposure Route of Most Concern

The *MRS* incorporates a number of the research needs identified in the *Mercury Study Report to Congress* and emphasizes the route of exposure portrayed in Figure 1. That exposure route begins when mercury is emitted from human activities (*i.e.,* anthropogenic sources) and becomes airborne for varying periods of time. Eventually, airborne mercury is deposited on land or water where it is transformed to organic forms of mercury (*i.e.,* methylmercury[3]). This methylmercury is taken up by fish and fish eaters (*e.g.*, larger fish, eagles, otters) and eventually can find its way into humans. Once in humans at high enough concentrations, methylmercury causes neurological damage and is particularly harmful to developing fetuses and young children (*i.e.,* under 6 years of age).

While the *Mercury Research Strategy* emphasizes the fish ingestion exposure pathway, it is not the only one of interest to the Agency. Inhalation is another exposure pathway of interest, but is not addressed in the *MRS*. A national multi-agency task force is looking at the ritualistic use of mercury[4]. While the *MRS* does not focus on ritualistic use, ORD intends to work with the task force on this route of exposure, and as appropriate, will work with other Agencies and organizations on other mercury exposure routes posing human and ecological risks.

The mercury transformations that occur in air, water, and on land and methylmercury's accumulation in fish, wildlife, and humans (based on the fish ingestion exposure pathway) present a set of scientific and technical challenges for both Agency regulators and researchers. With respect to mercury research, some of the challenges include, but certainly are not limited to, developing methods that accurately characterize mercury sources and

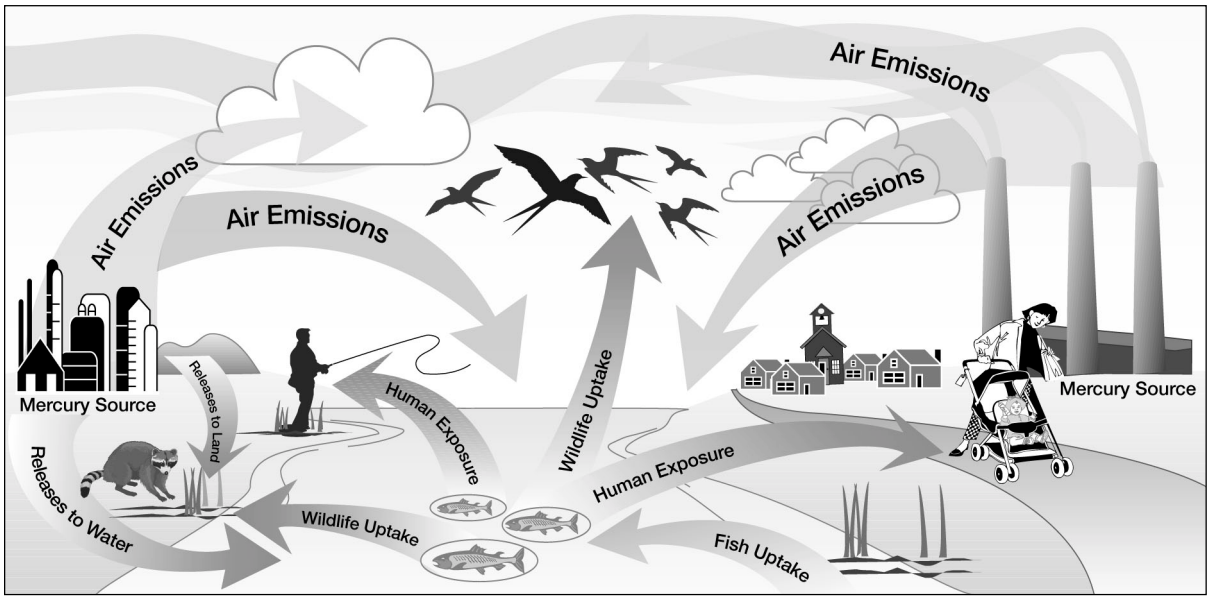

Figure 1. Mercury Fish Ingestion Exposure Pathway, the Focus of the *Mercury Research Strategy*.

the species of mercury released from those sources; understanding mercury transport and the transformations that occur in the air and water and on land; assessing mercury exposures to and effects on humans and ecosystems; and developing cost-effective ways to manage risks from mercury sources and sinks[5]. All of these challenges are addressed in the *MRS*.

1.2 INTERNATIONAL NEED TO ADDRESS MERCURY

Mercury is recognized internationally as an important pollutant warranting collaborative study and action. Virtually all countries have a common interest in mercury, since they are mercury exporters and importers via atmospheric transport. Domestic mercury reductions are only one component, albeit a very important one, for managing mercury risks in the United States. Another component is a better technical understanding of global mercury sources and circulation patterns, as well as improved estimates of global contributions to domestic ambient mercury levels. To successfully influence changes in mercury use and emissions abroad, the United States must share mercury control technology and engage in international risk management activities addressing mercury reductions. The rapid industrialization of China and other Asian nations and the resulting increased role of coal in those countries suggest an increasing emphasis on protecting the United States from international mercury sources.

Attention to monitoring and modeling (including speciation) along all U.S. borders for transboundary transport (both entering and exiting) and deposition of mercury are priorities. Preliminary studies suggest that:

- air masses from Asia reach the west coast of the United States in 3-4 days (Jaffe, et al., 1999);
- the Arctic receives 33 percent of its heavy metals deposition from industrial sources in Europe and North America (AMAP, 1997);
- trans-Atlantic transport could bring mercury species to South Florida as a consequence of dust storms in the Sahara Desert (Landis, et al., 2000).
- mercury transits to and from the United States, Canada, and Mexico (Nriagu, 1999).

EPA's long-range modeling analysis of domestic anthropogenic sources, as reported in the *Mercury Study Report to Congress*, found that there is no region of the United States where mercury deposition is not occurring. The range of deposition spans two orders of magnitude (0.5 - 50 µg per square meter per year) (EPA, 1997a). EPA is just beginning to focus on the regional, intercontinental, and global dimensions of mercury. One team of investigators has estimated that Asian sources account for about 46 percent of the anthropogenic mercury global total (Pirrone, et al., 1996). While combustion sources are a significant concern, there are uncertainties in the understanding of mercury emissions from non-combustion sources such as mercury cell chlor-alkali facilities. Globally, 200-300 factories hold approximately 50-60 million pounds of mercury and require 2-3 million pounds of new mercury annually to replenish consumption during production (Anscombe, 2000).

There is a growing appreciation of the global nature of the mercury problem and also of the need for joint action. EPA is currently exploring, with the Department of State (DOS), a variety of mechanisms and activities to elevate attention to mercury internationally. As a foundation for an international focus, the Agency now plans to develop an *International Mercury Strategy*. This international strategy will provide a framework and rationale for guiding the Agency's efforts, in concert with other agencies and the international community. It will facilitate development of global coordination and action on risk assessment and risk management for mercury. The international strategy will address how best to: (1) obtain and apply international routine emissions (including speciation) and multimedia monitoring and modeling information; (2) obtain and apply international research on exposure, effects, ecological and human risk assessment, and risk management research information; and (3) develop and implement risk management objectives in pollution prevention, capacity building, training, technology transfer and international formal deliberations, such as treaties or other mechanisms.

1.3 MERCURY RESEARCH STRATEGY ORGANIZATION

The *MRS* addresses a range of topics, including sources of mercury releases, air emission sources, human health and wildlife impacts, transport and fate of mercury in the environment, and techniques to manage risks from the largest emitting sources. It is organized as follows:

- Chapter 2.0 describes the challenges associated with mercury from source to receptor, including a discussion of mercury emissions and releases; mercury transport, transformation and fate; impacts of methylmercury on human and wildlife health; and mercury and methylmercury risk management.
- Chapter 3.0 explains why the *MRS* was developed and includes: the findings of the National Academy of Sciences (NAS) on the methylmercury reference dose (RfD); regulatory commitments on mercury by Agency Programs; voluntary efforts to prevent or minimize mercury in products, processes and wastes; and international opportunities to reduce mercury on a global scale.

- Chapter 4.0 summarizes the research efforts being performed by public and private organizations (*e.g.* federal, state, and local governments; academic institutions; the private sector) as well as international research efforts that will complement the research areas discussed in the *MRS*.
- Chapter 5.0 presents the key scientific questions and the strategic directions for EPA's mercury research program over the next five years, and identifies EPA's research priorities. It also provides detailed descriptions of the research needs to be addressed under each of the six key scientific questions.
- Chapter 6.0 identifies issues beyond research that deserve attention and are supportive of the *Mercury Research Strategy*. It also describes future opportunities for engagement and partnering with a variety of stakeholders (*e.g.*, regulated entities, environmental groups, community decision-makers at all levels, the general public, international entities).
- Chapter 7.0 contains the set of references cited in the *Mercury Research Strategy*.
- Appendix A includes a summary of nine transport and fate grants awarded in FY 1999 as part of ORD's STAR Grants Program.

1. The *Mercury Study Report to Congress* identified methylmercury as the mercury chemical species of greatest environmental concern. Volume V of the Mercury Study Report to Congress and the toxicology profile on mercury developed by the Agency for Toxic Substances and Disease Registry (ATSDR, 1999) provide more information on the adverse human health effects of inorganic mercury.

2. For the purposes of the *Mercury Research Strategy*, releases include all forms of mercury entering the environment (i.e., air, water, deposited on land). The term emissions deals with mercury entering the air. The term effluents deals with waterborne mercury entering water or depositing on land.

3. For the purposes of the *Mercury Research Strategy*, "mercury" refers to all forms of the element prior to methylation. Adverse human and ecological effects of the element occur from methylmercury exposures reflecting the chemical species bioconcentrated in the aquatic food web. Consequently, the term "methylmercury" is used when describing mercury in fish and the adverse health effects of mercury via the fish ingestion exposure pathway. When describing Agency programs, efforts, and documents the generic term "mercury" is used for all chemical species of mercury.

4. The task force is co-led by EPA's Office of Emergency and Remedial Response (OERR) and the Agency for Toxic Substances and Disease Registry (ATSDR). In the near term, the task force plans to convene an external expert panel to address the issue of ritualistic use, develop a tool kit to help local and state governments respond to ritualistic use problems, sponsor a pilot investigation to better understand the scope and nature of the exposure and prepare a national strategy on how to deal with the issue of ritualistic use.

5. For the purposes of the *Mercury Research Strategy*, sources are generally locations (e.g., points, areas) of mercury releases, including emissions, from human activities and sinks are locations of mercury deposition. It is recognized that sources may also be natural mercury sources and sources that re-emitted mercury. In some cases, sinks may act as re-emission sources, depending upon their location and the form of the mercury present in the sink.