



TOXICS RELEASE INVENTORY

Guidance for Reporting the Dioxin and Dioxin-like Compounds Category

Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) requires certain facilities manufacturing, processing, or otherwise using listed toxic chemicals to report the annual quantity of such chemicals entering each environmental medium. Such facilities must also report pollution prevention and recycling data for such chemicals, pursuant to section 6607 of the Pollution Prevention Act, 42 U.S.C. 13106. EPCRA section 313 is also known as the Toxics Release Inventory (TRI).

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DISCLAIMER

This guidance document is intended to assist industry with EPCRA section 313 reporting for the dioxin and dioxin-like compounds category. In addition to providing an overview of aspects of the statutory and regulatory requirements of the EPCRA section 313 program, this document also provides recommendations and emissions factors to assist industry with EPCRA reporting. These recommendations do not supersede any statutory or regulatory requirements, are subject to change, and are not independently binding on either EPA or covered facilities. Additionally, if a conflict exists between guidance on this site and the statutory or regulatory requirements, the conflict must be resolved in favor of the statute or regulation.

Although EPA encourages industry to consider these recommendations and emissions factors, in reviewing this document, industry should be aware that these recommendations and emissions factors were developed to address common circumstances at typical facilities. The circumstances at a specific facility may significantly differ from those contemplated in the development of this document. Thus, individual facilities may find that the recommendations and emissions factors provided in this document are inapplicable to their processes or circumstances, and that alternative approaches or information are more accurate and/or more appropriate for meeting the statutory and regulatory requirements of EPCRA section 313. To that end, industry should use facility specific information and process knowledge, where available, to meet the requirements of EPCRA section 313. EPCRA section 313 also provides that, in the absence of such readily available data, a reporting facility may make reasonable estimates to meet those EPCRA section 313 requirements. Facilities are encouraged to contact the Agency with any additional or clarifying questions about the recommendations and emissions factors in this document, or if the facility believes that EPA has incorrectly characterized a particular process or recommendation.

Additional guidance documents, including industry specific and chemical specific guidance documents, are also available on TRI's GuideME website:

https://ofmpub.epa.gov/apex/guideme_ext/f?p=guideme:gd-list

SECTION 1.0 INTRODUCTION

Section 1.1 Background

This document contains guidance information specific to reporting dioxin and dioxin-like compounds to the Toxics Release Inventory (TRI). For background on the TRI program, resources for determining whether a facility must report, and reporting requirements, please refer to the current TRI Reporting Forms and Instructions, also available on GuideME.

On October 29, 1999, the Environmental Protection Agency (EPA) promulgated a final rule (64 FR 58666) adding a category of dioxin and dioxin-like compounds to the list of toxic chemicals subject to the reporting requirements under section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA). The reporting threshold for the category was also established as 0.1 grams manufactured, processed, or otherwise used. The category listing is:

Dioxin and dioxin-like compounds (Manufacturing; and the processing or otherwise use of dioxin and dioxin-like compounds if the dioxin and dioxin-like compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical) (40 CFR 372.65(c))

The purpose of this document is to provide guidance on the reporting requirements of EPCRA section 313 for the dioxin and dioxin-like compounds category. EPCRA section 313 covered facilities that exceed the reporting threshold for the dioxin and dioxin-like compounds category are subject to the EPCRA section 313 annual reporting requirements beginning with reporting year 2000, with the first reports due by July 1, 2001.

This document explains the EPCRA section 313 reporting requirements and provides guidance on how to estimate annual releases and other waste management quantities of dioxin and dioxin-like compounds to the environment from certain industries and industrial activities. Because each facility is unique, the recommendations presented may have to be adjusted to the specific nature of operations at your facility or industrial activity.

The objectives of this guidance document are to:

- List EPCRA section 313 reporting requirements for the dioxin and dioxin-like compounds category;
- Promote consistency in the method of estimating annual releases and other waste management quantities of dioxin and dioxin-like compounds for particular industries and industrial classes;
- Reduce the level of effort expended by those facilities that prepare an EPCRA section 313 report for the dioxin and dioxin-like compounds category.

Section 1.2 What are the Reporting Thresholds?

Thresholds are specified amounts of toxic chemicals manufactured, processed, or otherwise used during the calendar year that trigger reporting requirements. The EPCRA section 313 dioxin and dioxin-like compounds category consists of seventeen specific compounds (see Section 1.4, Table 1-2) that are reported as a single chemical category. EPA regulations require threshold determinations for chemical categories to be based on the total mass of all the chemicals in that category (40 CFR 372.25(d)).

Reporting is required for the dioxin and dioxin-like compounds category:

- If a facility *manufactures* 0.1 grams of dioxin and dioxin-like compounds over the calendar year.
- If a facility *processes* 0.1 grams of dioxin and dioxin-like compounds over the calendar year. (See the category qualifier in Section 1.5)

- If a facility *otherwise uses* 0.1 grams of dioxin and dioxin-like compounds over the calendar year. (See the category qualifier in Section 1.5)

The qualifier for the dioxin and dioxin-like compounds category places some limitations on what is covered by the category and thus certain processing or otherwise use activities that may involve dioxin and dioxin-like compounds are not reportable. See Section 1.5 for a detailed discussion of the qualifier and its impacts on reporting.

The quantities of dioxin and dioxin-like compounds included in threshold determinations are not limited to the amounts of these compounds released to the environment, they include all amounts of dioxin and dioxin-like compounds manufactured, processed, or otherwise at the facility. For example, some emissions factors may include values for both before and after scrubbers, and while the after scrubber values would apply to release estimates, the before scrubber values would apply towards threshold calculations since this represents amounts that have been manufactured. Amounts estimated to be removed by scrubbers should also be reported according to how they are handled (e.g., released to land on-site, transferred off-site for disposal or destruction, etc.). If the only information that a facility has concerning the manufacturing, processing, or otherwise use of dioxin and dioxin-like compounds at the facility comes from emissions factors, then those quantities can be used to determine threshold quantities.

EPA regulations require threshold determinations, and release and other waste management quantities for chemical categories to be based on the total mass of all the chemicals in the category (40 CFR 372.25(d)). Thus, in determining thresholds and release and other waste management quantities the amounts of all members of the category must be summed and included in the calculations. As with reporting for all EPCRA section 313 categories, one Form R is prepared for the dioxin and dioxin-like compounds category that contains the total amounts of all members of the category. All reporting for the dioxin and dioxin-like compounds category is to be in gram quantities (40 CFR 372.85), no reporting in grams of toxic equivalents (TEQs) is allowed. It is important to remember that EPCRA section 313 does not require any additional testing. As stated in EPCRA section 313(g)(2):

[i]n order to provide the information required under this section, the owner or operator of a facility may use readily available data (including monitoring data) collected pursuant to other provisions of law, or, where such data are not readily available, reasonable estimates of the amounts involved. Nothing in this section requires the monitoring or measurement of the quantities, concentration, or frequency of any toxic chemical released into the environment beyond that monitoring and measurement required under other provisions of law or regulation.

Section 1.3 What is Form R Schedule 1?

On May 10, 2007 (72 FR 26544), EPA published a final rule that expanded the reporting for the dioxin and dioxin-like compounds category to include member specific data for certain reporting elements. The member specific data is used by EPA to perform toxic equivalency (TEQ) computations which are made available to the public. The member specific data is captured on the Form R Schedule 1 which is an adjunct to the Form R that mirrors the data elements from Form R Part II Chemical-Specific Information sections 5, 6, and 8 (current year only). Form R Schedule 1 requires the reporting of the individual grams data for each member of the dioxin and dioxin-like compounds category present. Facilities that file Form R reports for the dioxin and dioxin-like compounds category are required to determine if they have any of the information required by the Form R Schedule 1. Facilities that have any of the information required by Form R Schedule 1 must submit individual member data via the Form R Schedule 1 in addition to the Form R.

The only data reported on the Form R Schedule 1 is the mass quantity information required in sections 5, 6, and 8 (current year only) of the Form R. All of the other information required in sections 5, 6, and 8 of the Form R (off-site location names, stream or water body names, etc.) would be the same so this

information is not duplicated on Form R Schedule 1. For example, if a facility reported 5.3306 grams on Form R Section 5.1 for fugitive or non-point air emissions for the dioxin and dioxin-like compounds category then the facility would report on the Form R Schedule 1 the grams data for each individual member of the category that contributed to the 5.3306-gram total. The sum of the gram quantities reported for each individual member of the category should equal the total gram quantity reported for the category on Form R for each data element (see examples in Figure 1-1). The Form R Schedule 1 provides boxes for recording the gram quantities for all 17 individual members of the dioxin and dioxin-like compounds category. The boxes on the Form R Schedule 1 for each release type are divided into 17 boxes. Each of the boxes (1-17) corresponds to the individual members of the dioxin category as presented in Table. The NA box has the same meaning on Form R Schedule 1 as it does on the Form R and should only be marked if it is marked on the Form R. It is extremely important that facilities enter their grams data for the individual members of the category based on the order shown in Table 1-2: Members of the EPCRA Section 313 Dioxin and Dioxin-like Compounds Category. This information will be used to calculate toxic equivalency values using toxic equivalency factors that are specific to each member of the category.

More details on how to report using Form R Schedule 1 can be found in the annual “Toxic Chemical Release Inventory Reporting Forms and Instructions” available at:

https://ofmpub.epa.gov/apex/guideme_ext/f?p=guideme:rfi:::::rfi:5.

Form R Section 5 Example

SECTION 5. QUANTITY OF THE TOXIC CHEMICAL ENTERING EACH ENVIRONMENTAL MEDIUM ON-SITE					
			A. Total Release (pounds/year*) (Enter a range code** or estimate)	B. Basis of Estimate (Enter code)	C. Percent from Stormwater
5.1	Fugitive or non-point air emissions	NA <input type="checkbox"/>	5.3306	M2	

Form R Schedule 1 Section 5 Example

SECTION 5. QUANTITY OF DIOXIN AND DIOXIN-LIKE COMPOUNDS ENTERING EACH ENVIRONMENTAL MEDIUM ON-SITE									
		5.1	NA	5.2		NA	5.3		
		Fugitive or non-point air emissions		Stack or point air emissions		Discharges to receiving streams or water bodies (Enter data for one stream or water body per box) NA <input type="checkbox"/>			
						5.3.1	5.3.2	5.3.3	
D. Mass (grams) of each compound in the category (1-17)	1	0.0035							
	2	0.0059							
	3	0.0071							
	4	0.0008							
	5	0.0065							
	6	0.0923							
	7	0.5720							
	8	0.0723							
	9	0.0695							
	10	0.0399							
	11	0.3562							
	12	0.1309							
	13	0.0132							
	14	0.0815							
	15	1.4625							
	16	0.3126							
	17	2.1039							

If additional pages of Section 5.3 are attached, indicate the total number of pages in this box

and indicate the Section 5.3 page number in this box (Example: 1, 2, 3, etc.)

Figure 1-1: Hypothetical Form R, Section 5.1 and Form R Schedule 1, Section 5.1

Section 1.4 What are Dioxin and Dioxin-like Compounds and Which Chemicals are Included in the EPCRA Section 313 Dioxin and Dioxin-like Compounds Category?

Polychlorinated dibenzo-para(p)-dioxins (CDDs) and polychlorinated dibenzofurans (CDFs) constitute a group of persistent, bioaccumulative, toxic (PBT) chemicals that are termed ‘dioxin-like.’ The term, ‘dioxin-like’ refers to the fact that these compounds have similar chemical structure, similar physical-chemical properties, and invoke a common battery of toxic responses. An important aspect to this definition is that the CDDs and CDFs must have chlorine substitution of hydrogen atoms at the 2, 3, 7, and 8 positions on the benzene rings.

A molecule of dibenzo-p-dioxin (DD) and dibenzofuran (DF) is a triple-ring structure consisting of two benzene rings interconnected by a third oxygenated ring (i.e., a ring containing an oxygen atom). In DD, the middle oxygenated ring contains two oxygen atoms that connect the benzene rings while in DF, the oxygenated ring contains one oxygen atom that joins the benzene rings. The molecular structure of DD and DF is depicted in Figure 1-2. As can be discerned in Figure 1-2, there is the possibility of substituting hydrogen atoms with chlorine atoms (or other halogens) at eight substituent positions along the DD and DF molecules (i.e., positions 1, 2, 3, 4, 6, 7, 8, or 9). This pattern of substitution creates the possibility of 75 chlorodibenzo-p-dioxin and 135 chlorodibenzofuran compounds. These individual compounds are

technically referred to as congeners. Homologue groups are groups of congeners that have the same number of chlorine atoms attached to the molecule, but substituted in different positions as indicated by Cl_x and Cl_y in Figure 1-2. The prefix mono, di, tri, tetra, penta, hexa, hepta, and octa designates the total number of chlorines in the nomenclature of homologue groupings (i.e., molecules with either 1, 2, 3, 4, 5, 6, 7, or 8 chlorine atoms attached to the carbons). Isomerism is another important chemical descriptor, and refers to compounds with the same molecular formula (e.g., the same number of carbon, hydrogen, and chlorine atoms) but that differ by the location of the chlorine atoms on the benzene rings. Table 1-1 displays the total number of positional CDD and CDF isomers that are possible within each homologue group. The compounds with chlorine substitution in the 2, 3, 7, 8-positions on the molecule are the most toxic and bioaccumulate in mammalian systems, including humans.

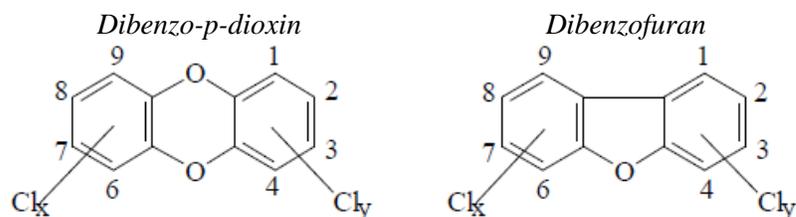


Figure 1-2: Chemical Structure of Dioxin-Like Compounds

Table 1-1: Homologues and Positional Isomers of CDDs, CDFs

Homologue (prefix)	Chlorine Atoms	Isomers of CDDs	Isomers of CDFs
Mono	1	2	4
Di	2	10	16
Tri	3	14	28
Tetra (T)	4	22	38
Penta (Pe)	5	14	28
Hexa (Hx)	6	10	16
Hepta (Hp)	7	2	4
Octa (O)	8	1	1
Total possible congeners		75	135

The EPCRA section 313 dioxin and dioxin-like compounds category consists of seventeen specific CDD and CDF compounds. Only those CDD and CDF compounds with chlorine substitution in the 2, 3, 7, 8-positions on the molecule are reportable under the EPCRA section 313 dioxin and dioxin-like compounds category. Table 1-2 lists all of the members of the EPCRA section 313 dioxin and dioxin-like compounds category by CAS number, name and abbreviated name. These are the only CDD and CDF compounds that are reportable under the EPCRA section 313 dioxin and dioxin-like compounds category. The term “dioxin,” as in “dioxin and dioxin-like compounds” refers to the most widely studied of these compounds, 2,3,7,8-tetrachlorodibenzo-p-dioxin (CAS No. 1746-01-6). Throughout this document the phrase “dioxin and dioxin-like compounds” refers to the seventeen chemicals listed in Table 1-2.

Table 1-2: Members of the EPCRA Section 313 Dioxin and Dioxin-like Compounds Category

CAS No.	Chemical Name	Abbreviated Name	#Label*
Polychlorinated Dibenzo-para(p)-dioxins			
1746-01-6	2,3,7,8-tetrachlorodibenzo-p-dioxin	2,3,7,8-TCDD	1
40321-76-4	1,2,3,7,8-pentachlorodibenzo-p-dioxin	1,2,3,7,8-PeCDD	2
39227-28-6	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-HxCDD	3
57653-85-7	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-HxCDD	4
19408-74-3	1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	1,2,3,7,8,9-HxCDD	5
35822-46-9	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	1,2,3,4,6,7,8-HpCDD	6
3268-87-9	1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin	1,2,3,4,6,7,8,9-OCDD	7
Polychlorinated Dibenzofurans			
51207-31-9	2,3,7,8-tetrachlorodibenzofuran	2,3,7,8-TCDF	8
57117-41-6	1,2,3,7,8-pentachlorodibenzofuran	1,2,3,7,8-PeCDF	9
57117-31-4	2,3,4,7,8-pentachlorodibenzofuran	2,3,4,7,8-PeCDF	10
70648-26-9	1,2,3,4,7,8-hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	11
57117-44-9	1,2,3,6,7,8-hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	12
72918-21-9	1,2,3,7,8,9-hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	13
60851-34-5	2,3,4,6,7,8-hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	14
67562-39-4	1,2,3,4,6,7,8-heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	15
55673-89-7	1,2,3,4,7,8,9-heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	16
39001-02-0	1,2,3,4,6,7,8,9-octachlorodibenzofuran	1,2,3,4,6,7,8,9-OCDF	17

*For filling out the distribution of each member of the category on Form R Schedule 1.

1.4.1 Formation of Dioxin and Dioxin-like Compounds During Combustion

More than a decade of combustion research has contributed to a general understanding of the central molecular mechanisms that form CDDs and CDFs emitted from combustion sources. Current understanding of the conditions necessary to form CDDs and CDFs were primarily derived from studying full-scale municipal solid waste incinerators (MSWIs), augmented with observations involving the experimental combustion of synthetic fuels and feeds within the laboratory. However, the formation mechanisms elucidated from these studies are generally relevant to most combustion systems in which organic material is burned with chlorine. Intensive studies have examined MSWIs from the perspective of identifying the specific formation mechanism(s) that occur within the system. This knowledge may lead to methods that prevent the formation of CDDs and CDFs and their release into the environment. Although much has been learned from such studies, how to completely prevent CDDs/CDFs from forming during the combustion of certain organic materials in the presence of a source of chlorine and oxygen is still unknown. The wide variability of organic materials incinerated and thermally processed by a wide range of combustion technologies that have variable temperatures, residence times, and oxygen requirements adds to this complex problem. However, central chemical events that participate in forming CDDs and CDFs can be identified by evaluating emission test results from MSWIs in combination with laboratory experiments.

CDD/CDF emissions from combustion sources can potentially be explained by three principal mechanisms, which should not be regarded as being mutually exclusive. The first is that CDDs and CDFs are present as contaminants in the combusted organic material and pass through the furnace and are emitted unaltered. The second is that CDD/CDFs ultimately form from the thermal breakdown and

molecular rearrangement of precursor ring compounds, which are defined as chlorinated aromatic hydrocarbons with a structural resemblance to the CDD and CDF molecules. Ringed precursors emanated from the combustion zone are a result of the incomplete oxidation of the constituents of the feed (i.e., products of incomplete combustion). The third mechanism, similar to the second, is that CDD/CDFs are synthesized *de novo*. *De novo* synthesis describes a pathway of forming CDD/CDFs from heterogeneous reactions on fly ash involving carbon, oxygen, hydrogen, chlorine, and a transition metal catalyst. With these reactions, intermediate compounds having an aromatic ring structure are formed. Studies in this area suggest that aliphatic compounds, which arise as products of incomplete combustion, may play a critical role in initially forming simple ring molecules, which later evolve into complex aromatic precursors. CDD/CDFs are then formed from the intermediate compounds. In both mechanisms (2) and (3), formation occurs outside the furnace, in the so-called post-combustion zone. Particulate bound carbon is suggested as the primary reagent in the *de novo* syntheses pathway.

Although chlorine is an essential component for the formation of CDD/CDFs in combustion systems, the empirical evidence indicates that, for commercial scale incinerators, chlorine levels in feed are not the dominant controlling factor for rates of CDD/CDF stack emissions. Important factors which can affect the rate of CDD/CDF formation include the overall combustion efficiency, post-combustion flue gas temperatures and residence times, and the availability of surface catalytic sites to support CDD/CDF synthesis. Data from bench, pilot and commercial scale combustors indicate that CDD/CDF formation can occur by a number of mechanisms. Some of these data, primarily from laboratory and pilot scale combustors, have shown direct correlation between chlorine content in fuels and rates of CDD/CDF formation. Other data, primarily from commercial scale combustors, show little relation with availability of chlorine and rates of CDD/CDF formation. The conclusion that chlorine in feed is not a strong determinant of CDD/CDF emissions applies to the overall population of commercial scale combustors. For any individual commercial scale combustor, circumstances may exist in which changes in chlorine content of feed could affect CDD/CDF emissions. For uncontrolled combustion, such as open burning of household waste, chlorine content of wastes may play a more significant role in affecting levels of CDD/CDF emissions than observed in commercial scale combustors. For a more detailed discussion of the mechanisms of formation and the role of chlorine in the formation kinetics, the reader may refer to: Part 1: Estimating Exposure to Dioxin-Like Compounds; Volume 1: *Sources of Dioxin-Like Compounds in the United States*; Chapter 2: *Mechanisms of formation of dioxin-like compounds during combustion of organic materials*; In: Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-dioxin. EPA/600/P-00/001Cb, December 2003. NAS Review Draft. Available at: https://cfpub.epa.gov/ncea/iris_drafts/dioxin/nas-review/pdfs/part1_vol1/dioxin_pt1_vol1_ch02_dec2003.pdf

Section 1.5 What Activities are Covered by the Qualifier for the Dioxin and Dioxin-like Compounds Category?

The dioxin and dioxin-like compounds category has the following activity qualifier that describes what must be reported under the category:

“Manufacturing; and the processing or otherwise use of dioxin and dioxin-like compounds if the dioxin and dioxin-like compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical.”

This qualifier states that if a facility manufactures dioxin and dioxin-like compounds then those quantities must be applied towards the 0.1-gram manufacturing threshold and included in release and other waste management calculations. Manufacture includes the coincidental production of dioxin and dioxin-like compounds during any process (e.g., a combustion process, a chemical manufacture process). Note that the EPCRA section 313 definition of manufacture includes importing. The qualifier also covers the processing or otherwise use of dioxin and dioxin-like compounds, but only if the dioxin and dioxin-like

compounds are present as contaminants in a chemical and if they were created during the manufacturing of that chemical. This means that if a facility processes or otherwise uses a chemical or mixture that contains dioxin and dioxin-like compounds that were created during the manufacturing of that chemical or mixture, then the dioxin and dioxin-like compounds must be included in threshold determinations and release and other waste management calculations. However, if the dioxin and dioxin-like compounds were already present in a product being processed or otherwise used and were not created during the manufacture of that product (such as at food processing plants where dioxin and dioxin-like compounds may be present in the incoming raw materials) the dioxin and dioxin-like compounds are not reportable and do not need to be included in threshold determinations or release and other waste management calculations.

Examples of the impacts of the dioxin and dioxin-like compounds category qualifier on what is reportable:

Example 1: A facility manufactures chemical A and in doing so, the facility also manufactures dioxin or dioxin-like compounds. Because EPCRA section 313 defines “manufacturing” to include production, the facility would have to include the dioxin or dioxin-like compounds it produced in its threshold determinations and release and other waste management calculations. This is true regardless of whether the compounds are present as contaminants in chemical A since the chemical listing for dioxin or dioxin-like compounds contains no modifications to the term manufacture as defined under EPCRA section 313.

Example 2: A facility processes or otherwise uses chemical A. Dioxin or dioxin-like compounds are present in chemical A as contaminants. The dioxin or dioxin-like compounds present in chemical A were created during the manufacturing of chemical A. In this case, the facility would have to include the dioxin or dioxin-like compounds present in chemical A in its threshold determinations and release and other waste management calculations.

Note that if chemical A is processed into a different product but chemical A still exists in that product (i.e., it has not been converted into a different chemical) then the dioxin and dioxin-like compounds must be included in threshold determinations and release and other waste management calculations.

Example 3: A facility processes or otherwise uses chemical B. Dioxin or dioxin-like compounds are present in chemical B as contaminants. However, the dioxin or dioxin-like compounds in chemical B were not created during the manufacturing of chemical B (they were introduced from an environmental source or created during the manufacture of a precursor to chemical B). In this case, because one of the two limitations in the category qualifier was not satisfied, the facility would not have to include the dioxin or dioxin-like compounds present in chemical B in its threshold determinations and release and other waste management calculations.

Example 4: Dioxin or dioxin-like compounds are present in chemical A as contaminants. The dioxin or dioxin-like compounds present in chemical A were created during the manufacturing of chemical A. Facility X uses or processes chemical A to manufacture chemical C. No new dioxin or dioxin-like compounds were created in the manufacture of chemical C, but chemical C does contain the dioxin or dioxin-like chemicals that were present in chemical A. Because facility X is using or processing chemical A, which contains dioxin or dioxin-like compounds as contaminants that were created during the manufacturing of chemical A, facility X would have to include the dioxin or dioxin-like compounds present in chemical A in its threshold determinations and release and other waste management

calculations. This is true regardless of what facility X does with chemical C (uses it on site, sells it, etc.).

Facility X then sells chemical C to facility Y. Although chemical C contains dioxin or dioxin like compounds as contaminants, those compounds *were not* created during the manufacture of chemical C (they were created during the manufacture of chemical A). Because one of the two limitations in the category qualifier was not satisfied, facility Y *would not* have to include the dioxin or dioxin-like compounds present in chemical C in its threshold determinations and release and other waste management calculations.

Example 5: Facility X imports chemical D into the country. Chemical D contains dioxin or dioxin-like compounds. Because EPCRA section 313 defines “manufacturing” to include importing, facility X would have to include the dioxin or dioxin-like compounds present in chemical D in its threshold determinations and release and other waste management calculations. This is true regardless of whether the compounds are present as contaminants or when they were created since the chemical listing for dioxin or dioxin-like compounds contains no modifications to the term manufacture as defined under EPCRA section 313.

Facility X then sells chemical D to facility Y. Facility Y processes or uses chemical D on site. Facility Y must determine if the dioxin or dioxin-like compounds present in chemical D: 1) are present as contaminants, and 2) were created during the manufacture of chemical D. If the answers to *both* questions are “Yes,” then facility Y would have to include the dioxin or dioxin-like compounds present in chemical D in its threshold determinations and release and other waste management calculations. In answering those questions, facility Y should use the best available information.

Example 6: A waste management facility accepts wastes that contain dioxin or dioxin-like compounds for the purposes of on-site waste management. By accepting waste for on-site waste management, the facility is otherwise using the dioxin or dioxin-like compounds in that waste. The facility must determine if the dioxin or dioxin-like compounds in the waste: 1) are present as contaminants, and 2) were created during the manufacture of the waste or any chemicals in the waste. If the answers to *both* questions are “Yes,” then the facility would have to include the dioxin or dioxin-like compounds present in the waste in its threshold determinations and release and other waste management calculations. In answering those questions, the facility should use the best available information.

There are several chemicals and/or products that EPA has identified as having the potential to contain dioxin and dioxin-like compounds manufactured as byproducts during the manufacturing process for those chemicals. Some examples of these chemicals and their uses include, but are not limited to:

CAS No.	Chemical/Product Name	Typical Uses
118-75-2	Chloranil	dyes, pigments, pesticides
87-86-5	Pentachlorophenol (PCP)	wood preserving, pesticides
107-06-2	Ethylene dichloride (EDC) (manufactured by oxychlorination)	vinyl chloride production, gasoline, paints and varnishes, metal degreasing, scouring compounds, organic synthesis, solvent, fumigant
94-75-7	2,4-D	pesticides
1928-43-4	2,4-D Ester Herbicides Bleached chemical wood pulp	pesticides white paper products

Section 1.6 What Other Changes to the EPCRA Section 313 Reporting Requirements Apply to the Dioxin and Dioxin-like Compounds Category?

EPA has also made modifications and/or clarifications to certain reporting exemptions and requirements for the PBT chemicals that are subject to the lower reporting thresholds; this includes dioxin and dioxin-like compounds category. Please note that for dioxin and dioxin-like compounds, like other PBT chemicals, facilities cannot apply the *de minimis* exemption when making threshold determinations and release and other waste management calculations. PBT chemicals are also excluded from using the Alternate Reporting Threshold and Form A Certification Statement, and from using range reporting options when reporting releases and other waste management activities. More information on reporting PBT chemicals to TRI, or on the above exemptions and reporting options, can be found in the Reporting Forms and Instructions, available at: https://ofmpub.epa.gov/apex/guideme_ext/f?p=guideme:rfi-home.

1.6.1 Data Precision

Facilities should report for the dioxin and dioxin-like compounds category at a level of precision supported by the accuracy of the underlying data and the estimation techniques on which the estimate is based. However, the smallest quantity that needs to be reported on the Form R for the dioxin and dioxin-like compounds category is 0.0001 grams (i.e., 100 micrograms).

Example: If the total quantity for Section 5.2 of the Form R (i.e., stack or point air emissions) is 0.00005 grams or less, then zero can be entered. If the total quantity is between 0.00005 and 0.0001 grams then 0.0001 grams can be entered or the actual number can be entered (e.g., 0.000075).

SECTION 2.0 GUIDANCE ON ESTIMATING ENVIRONMENTAL RELEASES OF DIOXIN AND DIOXIN-LIKE COMPOUNDS

Section 2.1 General Guidance

EPA is providing the following guidance which may be used by facilities in estimating and reporting annual releases and other waste management quantities for the dioxin and dioxin-like compounds category. EPA supports the use of three different approaches for estimating annual releases of dioxin and dioxin-like compounds from facilities subject to reporting:

1. Use of actual facility-specific monitoring data
2. Use of facility-specific emissions factors
3. Use of facility-specific EPA default emissions factors

In general EPA considers these three approaches to be hierarchical. In most situations, monitoring or directly measured data obtained at your facility provides the best and most accurate estimate of annual releases of dioxin and dioxin-like compounds. Note that, as discussed under Section 1.2, EPCRA section 313 does not require any additional monitoring or measurements beyond that monitoring and measurement required under other provisions of law or regulation. Depending on the adequacy and quality of the data in terms of sampling and laboratory methods used to ascertain the data, monitoring data may or may not be a facility's best available data. To be representative of annual releases of dioxin and dioxin-like compounds, the monitoring and sampling should have been taken under conditions representative of the facility's general operating and/or production conditions. In the absence of such monitoring data two additional approaches are recommended, which, to the extent possible, should also be based on conditions representative of the facility's general operating and/or production conditions.

- First, facilities may use facility-specific emissions factors that they believe are the best 'fit' to their facility. This means that the facility may use emissions factors developed from the sampling and monitoring of dioxin and dioxin-like compounds at a similar facility. Reports of sampling emission and effluent streams should be collected and reviewed from facilities that are most similar in technology, design, operation, capacity, auxiliary fuels used, products produced, the manufacturing process, waste products generated, Industrial Classification Code, feedstocks used, air/water pollution control systems, etc. An important aspect in selecting an emissions factor for a combustion process is temperature. A temperature inlet to the air pollution control device that is below 200° Celsius or above 450° Celsius will result in minimal stack release of dioxin and dioxin-like compounds. Therefore, in defining similarity of process, the facility operator is encouraged to examine, and then match, the temperature reported at the facility that you selected to be representative of potential emissions from your facility. Data from similar facilities within the same industry sector compiled by industry technical organizations may be a good source of facility-specific emissions factors.
- Second, facilities that cannot use either of these approaches may estimate their annual releases through the use of default emissions factors provided by EPA in SECTION 4.0 of this document. Selection of more site-specific emissions factors are preferred.

The owner/operator of the facility should determine whether one of these three approaches would provide an accurate reflection of the potential for releases of dioxin and dioxin-like compounds from the facility or whether some other method would be more appropriate. Figure 2-1 is a 'decision tree' highlighting the basic questions one should ask when selecting the appropriate emissions factor approach. The first step in the 'decision tree' is to determine whether your facility meets the reporting requirements of EPCRA section 313; however, it is possible that before you can make a final determination on whether your

facility meets the EPCRA section 313 reporting requirements you may have to go ahead and use one of the estimation methods to help determine if your facility will exceed reporting thresholds.

When selecting the estimation method to be used, EPA recommends that the facility be able to document the rationale employed in making the selection. When documenting the annual releases and other waste management quantities of dioxin and dioxin-like compounds, EPA recommends that the facility indicate which of these three approaches was used in deriving the estimate. The owner/operator is encouraged to exercise ‘best engineering judgement’ when arriving at the decision on the most appropriate approach to use. A more detailed explanation of each of these approaches follows.

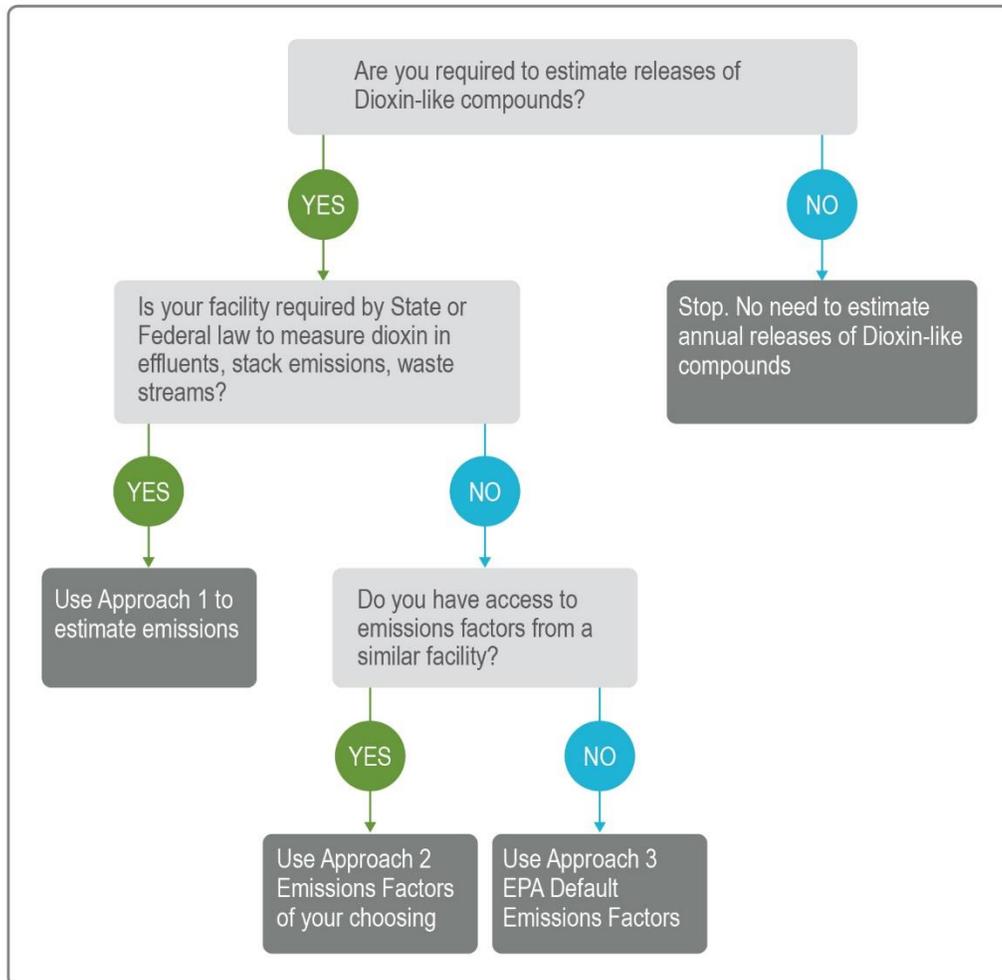


Figure 2-1: Decision Tree for Selecting Emissions Estimation Technique

In the context of this guidance, the term “best engineering judgment” engenders one or more of the following:

- Knowledge of the manufacturing/industrial process and process flow;
- Knowledge of the chemical feed stocks used in the manufacturing/industrial process;
- Knowledge of the feedstocks/fuels used in providing a source of energy for the process;
- Knowledge of the water pollution control system/technology and contaminant removal efficiencies used to treat industrial wastewater;
- Knowledge of the waste products derived from operations and manufacturing;
- Knowledge of the air pollution control equipment and contaminant removal efficiencies used to control toxic air pollutants.

When applying ‘best engineering judgement’ to a determination of the appropriate emissions factor approach to use to calculate emissions and releases of dioxin-like compounds for your facility, it is important to:

- Obtain engineering test reports and/or literature references of dioxin emissions/releases from facilities that are within your industry code (NAICS or SIC).
- Compare your facility design, function and operations with other facilities that have been tested or sampled for emissions of dioxin-like compounds. This will allow you to match the two processes and make the determination as to how representative these emissions factors are to your facility;
- If you are unable to locate representative emissions factors for your facility, then you may elect to use EPA’s default emissions factors appropriate for your facility.

2.1.1 Approach 1 - Use Actual Facility-Specific Monitoring Data

This approach allows the facility to estimate annual releases of dioxin and dioxin-like compounds to the air, water and land, as well as other waste management quantities, based on measured data derived at the facility. A facility may be required to perform monitoring under provisions of the Clean Air Act (CAA), the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), or other regulations. If this is the case, then these data should be available for developing release estimates. Data may have also been collected for your facility for compliance monitoring purposes associated with a state or federal permit. If only a small amount of direct measurement data is available or if you believe the monitoring data are not representative, you should determine if an alternative estimation method would give a more accurate result. With regard to the manner in which non-detects (ND) are reported, refer to Section 2.2.

2.1.2 Approach 2 - Use Facility-Specific Emissions Factors

Emissions factors are the fundamental tools in this guidance for estimating releases of dioxin and dioxin-like compounds. An emissions factor is a representative value that is intended to relate the quantity of dioxin and dioxin-like compounds released to the open environment with a measure of industrial activity associated with the release. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, or duration of the activity emitting the contaminant. Examples of emissions factors include: nanograms (ng) of dioxin and dioxin-like compounds emitted into air per kilogram (kg) of coal burned; picogram (pg) of dioxin and dioxin-like compounds discharged into surface water per liter (L) of wastewater; ng dioxin and dioxin-like compounds transferred to land disposal per kg of sludge produced at your facility. Emissions factors facilitate estimation of environmental releases from various sources of releases of dioxin and dioxin-like compounds when the annual activity level of the facility is known. Your emissions factor should be assumed to be representative of long-term averages for your facility. The general equation for emission estimation is:

Equation 1

Annual Release = Emissions Factor × Annual Activity Level

$$R = EF \times A$$

where:

R = annual release of dioxin and dioxin-like compounds, (i.e., g/yr)

A = activity level or production rate, (e.g., kg of material processed per year)

EF = dioxin emissions factor, (e.g., g dioxin released/kg material processed/time)

EF is to represent the emission of dioxin and dioxin-like compounds into the open environment at the 'end-of-the-pipe'. The extent of completeness and detail of the emissions is determined by the information available from published references. Emissions from some processes are better documented than others. When electing to use this approach, EPA recommends that the facility maintain documentation on the other facility(ies) engineering test reports or the source of the industry- specific data compiled by technical organizations that were evaluated and used in deriving your emissions factors. The documentation should clarify why the other facility is a close analogy to your facility based on similarity of design, operations, feed stocks, end products, industry code, manufacturing process, combustion process, and pollution control systems. Sources of information that may be helpful in Approach 2 include:

- **State or Tribe Regulatory Agencies.** In the development of regulatory requirements for specificities, it is often the case that state environmental agencies have issued permits for the allowable discharge of dioxin-like compounds to the environment from facilities similar to your own. A state or tribal agency may have reliable test reports information attendant to permitting such facilities. These test reports are usually kept in the public record.
- **Trade Associations.** Several industries are represented by Trade Associations that function to foster the interests of a particular industrial sector. Such trade associations are comprised of member companies. Often member companies make engineering test reports available to the Trade Association members.
- **EPA Regulatory Dockets.** EPA regulatory dockets are maintained as a central repository of information EPA used in a rule making process. Such dockets and their contents are open to the public for inspection and photocopying. The Federal Register preamble announcing proposed or final rule under one of the statutory authorities of EPA will identify the location of the regulatory docket and provide information as to how one may access information in the docket. The docket does contain technical information, including test reports data, that was used in the development of the regulatory requirements.
- **EPA Internet Sites.** The EPA maintains a central website, <https://www.epa.gov>. This home page provides a useful base from which to access EPA databases, reports and studies, and to conduct searches by topic. Complete documents can be electronically accessed from this site. An example of an EPA site having abundant information on air emissions factors is the Technical Air Pollution Resources maintained by EPA's Office of Air Quality Planning and Standards: <https://www.epa.gov/technical-air-pollution-resources>.
- **Engineering and Science Libraries.** Public and private universities often allow public access to technical literature housed within university libraries. This is particularly true of universities having schools of engineering and science.

2.1.3 Approach 3 - Use Facility-Specific EPA Default Emissions Factors

With this approach, EPA is providing tables of emissions factors for specific sources, that, when multiplied by an appropriate measure of annual activity level at your facility, will result in an estimate of annual releases of the sum of dioxin and dioxin-like compounds (i.e., the 17 compounds of CDDs and CDFs) from your facility. Emissions factors are used to calculate annual releases in situations in which the facility has not measured CDDs and CDFs in its effluents or emission streams. The EPA default emissions factors were derived from the available monitoring data deemed to be representative of the source category (or segments of the source category that differ in configuration, fuel type, manufacturing process, feedstocks, pollution control systems, etc.). Implicit in the use of the default emissions factors is the assumption that facilities with similar design and operating characteristics should have a similar potential for release of dioxin and dioxin-like compounds. The default emissions factors are more accurately applied to an entire source category, because it is representative of the average emissions of all tested facilities in the category. This introduces a significant degree of uncertainty when applying the average emissions factor to an individual facility, namely, that a portion of facilities within the industrial category will have emissions that are either above or below the average. However, in the absence of either monitoring data from your facility, or more accurate site-specific emissions factors, EPA believes that these default emissions factors can be used to make a reasonable estimation of releases.

The CDD and CDF EPA default emissions factors in this guidance were developed from three primary references:

- EPA's Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002B, September 2000.
- An Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the U.S. for the Years 1987, 1995, and 2000 (Final, Nov 2006), U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-03/002F.
- Estimating Exposure to Dioxin-Like Compounds; Volume 2: Sources of Dioxin-Like Compounds in the United States, EPA/600/00/001, Draft Final, September, 2000.

The most recent versions of the first two documents above can be found at:

<https://www.epa.gov/dioxin/inventory-dioxin-sources-and-environmental-releases>

When researching emissions factors in Approach 2 (above), the owner and operator of a reporting facility may elect to use emissions factors developed for sources other than those listed in this guidance, for example, medical waste incinerators. The owner/operator of such a facility is encouraged to review sources and releases of dioxin-like compounds contained in EPA's Database (listed above) in order to assist in the selection of more appropriate emissions factors.

Section 2.2 Consideration of Non-Detects

When detected in emissions and effluents from facilities, dioxin and dioxin-like compounds are found in minute quantities, e.g., one part-per trillion (1 ppt) or less, and as mixtures of dioxin and the dioxin-like compounds. Detection is with high resolution gas chromatography combined with high resolution mass spectrometry. For example, EPA Method 1613 (USEPA, 1994a) (used to quantify CDDs and CDFs in wastewater, solids, air, and tissue samples) can reliably detect these compounds at or below one part per trillion (i.e., 10 parts per quadrillion (ppq) in water; 1 ppt in solid waste). This presents a challenge in terms of interpretation of results in which a CDD/CDF compound is reported by the analytical laboratory as 'Not Detected' (shown as the abbreviation 'ND' on lab sheets).

Even with these extremely low levels of detectability with current laboratory methods, it is not possible to know with certainty if 'not detected' (ND) is actually zero (i.e., that dioxin and dioxin-like compounds are not present in the sample) or if dioxin and dioxin-like compounds really are present in the sample at some concentration below the minimal detection limit (MDL). The monitoring data and emissions factors determined for your facility should be reported in a manner consistent with the methods and procedures that EPA has developed for determining if these compounds are present in various industrial processes. For example, EPA Method 1613 (USEPA, 1994a) indicates that laboratory results below the minimum detection level should be reported as ND or as required by the regulatory authority. For purposes of threshold determinations and the reporting of releases and other waste management quantities for dioxin and dioxin-like compounds under EPCRA section 313, either with monitoring data, or by using the emissions factor approach, non-detects are treated as 'zero' if that is how the method being used treats non-detects (e.g., Method 1613, Method 23). However, facilities should use their best readily available information to report, so if a facility has better information than provided by these methods then that information should be used. For example, if a facility is not detecting dioxin or a particular dioxin-like compound using a particular method but has information that shows that they should be detecting them the facility should use this other information and it may be appropriate to estimate quantities using one half the detection limit.

If the method being used by a facility to detect dioxin and dioxin-like compounds is not an EPA approved method and the detection level being used is not as sensitive as those approved for use under EPA methods, then EPA's EPCRA section 313 guidance with regard to non-detects should be followed. This guidance states that facilities must use reasonable judgement as to the presence and amount of a listed toxic chemical based on the best readily available information. An indication that a reportable chemical is below detection is not equivalent to stating that the chemical is not present. If the reportable toxic chemical is known to be present, EPA recommends that a concentration equivalent to half the detection limit be used. Facilities should not estimate releases solely on monitoring devices, they should also rely on their knowledge of specific conditions at the plant.

SECTION 3.0 EXAMPLES OF CALCULATING EMISSIONS TO THE AIR, WATER, AND LAND

Environmental releases of dioxin and dioxin-like compounds occur to all media: air, water and land. Dioxin and dioxin-like compounds are not intentionally manufactured, they are inadvertently formed during certain manufacturing and combustion processes. In this regard, dioxin releases cannot be determined by a mass balance of your facility. Rather EPA recommends you use one of the three approaches listed in SECTION 2.0, above (direct measurements, or the two emissions factor approaches). SECTION 4.0 gives EPA default emissions factors for specific facilities falling within certain reporting facility industrial codes. The purpose of this section is to give examples of calculating emissions to air, water and land from your facility. In some examples the phrase “dioxin and dioxin-like compounds” may be abbreviated to “D&DLC” to save space.

Section 3.1 Approach 1 - Use Actual Facility-specific Release Data

Example 1: Calculating Air Releases Using Stack Monitoring Data

Stack testing has determined that dioxin and dioxin-like compounds are detected in the stack gases at your facility at a concentration of 10 E-09 g per dry standard cubic meter of gas (10 ng/dscm). The moisture content in the stack is typically 10%. The stack gas velocity is typically 8.0 m/s. The diameter of the stack is 0.3 m. Calculate the annual air release of dioxin and dioxin-like compounds from the stack of your facility.

Step 1. Calculate volumetric flow of stack gas stream

Equation 2

Volumetric flow = (gas velocity) × (internal area of stack)

Volumetric flow = (gas velocity) × [(pi) × (internal stack diameter)² / 4]

Volumetric flow = (8.0 m/s) × [(pi) × (0.3m)² / 4]

Volumetric flow = 5.7 m³/s

Step 2. Correct volumetric flow for moisture content in stack gas stream

Stack gases may contain large amounts of water vapor. The concentration of the chemical in the exhaust is often presented on a ‘dry gas’ basis. For an accurate release rate, correct the stack or vent gas flow rate in Step 1 for the moisture content in your facility’s stack gas. This is done simply by multiplying the volumetric flow in Step 1 by the term (1 - fraction of water vapor). The dry gas volumetric flow rate can then be multiplied by the concentration of dioxin and dioxin-like compounds measured in the stack gases (see Step 3).

Equation 3

Dry volumetric flow = (volumetric flow) × (1 - fraction of water)

Dry volumetric flow (corrected) = (5.7 m³/s) × (1 - 0.10) = 5.13 m³/s

Step 3. Estimate annual stack emissions to air

Equation 4

$$R_{\text{air}} = C \times V \times CF \times H \times \{\text{units conversion factor}\}$$

where:

- R_{air} = Annual release of dioxin and dioxin-like compounds to air (g/yr)
- C = Combustion flue gas concentration of D&DLC (ng/dry standard cubic meter)
- V = Hourly Volumetric flow rate of combustion flue gas (dscm/hour)(20°C, 1 atm; adjusted to 7% O₂)
- CF = Capacity factor, fraction of time that the facility operates on an annual basis (e.g., 0.85)
- H = Total hours in a year (8,760 hr/yr)
- R_{air} = $(10 \text{ ng/dscm}) \times (5.13 \text{ dscm/s}) \times (3600 \text{ s/hr}) \times (8760 \text{ hr/yr}) \times (0.85) \times (g/10^9 \text{ ng})$
- R_{air} = 1.38 g/yr

Example 2: Calculating Water Releases Using NPDES Monitoring Data

Your facility is subject to NPDES permits for the discharge of dioxin and dioxin-like compounds into surface waters. You are required to conduct periodic monitoring of the effluent discharge from your facility. In this example, quarterly samples were taken to be analyzed for the content of dioxin and dioxin-like compounds. Each sample was an hourly, flowrate-based composite taken for one day to be representative of the discharge for that day. The total effluent volume for that day was also recorded. Your facility operates 350 days/year. The following data were collected on each sample day.

Quarter sample number	Discharge flow rate (10 ⁶ gal/day)	Dioxin and dioxin-like compounds concentration (pg/L)
1	20	10
2	20	10
3	40	10
4	100	10

To calculate the amount of dioxin and dioxin-like compounds discharged on each sample day, the concentration of dioxin and dioxin-like compounds in the discharge is multiplied by the discharge flow rate for that day, as shown below for the first quarter sample.

Step 1: Calculate the amount of dioxin and dioxin-like compounds discharged per day from each day of sampling.

Amount of dioxin and dioxin-like compounds/day = (daily effluent flow rate) × (dioxin and dioxin-like compounds concentration in effluent). From the table above, the calculation of daily dioxin and dioxin-like compounds effluent discharge for the first sampling quarter is:

Equation 5

$$\text{First Quarter Discharge} = (10 \text{ pg/L}) \times (1 \text{ g}/10^{12} \text{ pg}) \times (3.8 \text{ L/gal}) \times (20 \times 10^6 \text{ gal/day})$$

$$\text{First Quarter Discharge} = 0.00076 \text{ g dioxin and dioxin-like compounds/day}$$

Step 2: Find the average amount of dioxin discharged in effluent/day

Using the same equation, the second, third and fourth quarter dioxin and dioxin-like compounds monitoring events are calculated to be 0.00076 g/day; 0.0015 g/day; and 0.0038 g/day, respectively. Then the average daily dioxin and dioxin-like compounds discharge rate for all monitoring events at this facility is:

Equation 6

$$\text{Average daily discharge} = [(0.00076 + 0.00076 + 0.0015 + 0.0038) / 4 \text{ sampling periods}] \text{ g/day}$$

$$\text{Average daily dioxin and dioxin-like compounds discharge} = 0.0017 \text{ g/day}$$

Step 3 Calculate the annual discharge of dioxin to surface waters

Your facility operates 350 days/year. The estimated annual discharge of dioxin and dioxin-like compounds is calculated as follows:

Equation 7

$$\text{Annual Discharge of D\&DLC to Surface Water} = (350 \text{ day/yr}) \times (0.0017 \text{ g/day})$$

$$\text{Annual Dioxin and Dioxin-like Compounds Discharge to Surface Water} = 0.6 \text{ g/yr}$$

Under EPCRA section 313, the disposal of toxic chemicals in on-site landfills constitutes a release to land. Waste contaminated with dioxin and dioxin-like compounds may be placed in a RCRA Subtitle C landfill for disposal. The following is an example of calculating the annual quantity of dioxin and dioxin-like compounds disposed in a RCRA Subtitle C landfill.

Example 3: Estimating Releases to Land

Example: Land disposal of sludge. Your facility generates approximately 1 kg of dry sludge per 4000 L of wastewater treated at the facility's on-site industrial wastewater treatment plant. The facility operations produce approximately 100 million L of wastewater per day. Monitoring results indicate that the sludge, on average, contains approximately 3 ng dioxin and dioxin-like compounds per kg dry sludge produced. All of the sludge from your facility is placed in an on-site RCRA Subtitle C landfill. The facility operates 350 days per year. What is the annual amount of dioxin and dioxin-like compounds released to land from your facility as a function of land disposal of the sludge contaminated with dioxin and dioxin-like compounds?

Step 1: Determine the amount of sludge produced per day from the wastewater treatment process.

Equation 8

Total Sludge Generated = (1 Kg sludge/4000 L wastewater) × (1 × 10⁸ L wastewater/day)

Total Sludge Generated = 25,000 kg/day

Step 2: Determine the amount of dioxin and dioxin-like compounds contained in the sludge produced each day.

Equation 9

Total amount of D&DLC in sludge = Total sludge generated × average D&DLC concentration in sludge

Total amount of D&DLC in sludge = (25,000 kg sludge/day) × (3 ng D&DLC/kg of sludge) × (g/10⁹ ng)

Total amount of dioxin and dioxin-like compounds in sludge = 0.000075 g/day

Step 3 Calculate the annual release of dioxin and dioxin-like compounds to land based on annual days of operation per year

Equation 10

Annual release of dioxin and dioxin-like compounds to land = average daily D&DLC loading in sludge × total operating days per year.

Annual release of dioxin and dioxin-like compounds to land = (7.5 × 10⁻⁵ g D&DLC/day) × (350 operating days/yr)

Annual release of dioxin and dioxin-like compounds to land = 0.03 g/yr

Section 3.2 Examples of Estimating Releases Using Emissions Factors

You have either developed your own facility-specific emissions factors or have decided to use EPA's default emissions factors (refer to SECTION 4.0; EPA Default Emissions Factors) to estimate annual releases of dioxin and dioxin-like compounds from your facility to air, land and water. Emissions factors (EF) relate potential release of dioxin and dioxin-like compounds to the activity level of your facility. The units vary according to the units of measure of activity level, but usually are weight per unit weight of production or weight per unit volume related to production. A common EF for combustion processes is ng dioxin and dioxin-like compounds per kg material combusted, processed, or produced. A common EF for point source effluent discharges into surface waters is pg dioxin and dioxin-like compounds per L of wastewater discharged. A common EF for RCRA waste generated that will be disposed is pg dioxin and dioxin-like compounds per kg of waste or sludge generated. The following serve as examples of how to make calculations of annual releases of dioxin and dioxin-like compounds using either your own chosen emissions factors or EPA default emissions factors. In either case, the procedures are the same.

Example 4: Estimating Air Releases

The emissions factor that best fits your facility is 10 ng dioxin and dioxin-like compounds released from the stack per kg of materials processed. Each day your facility processes 25,000 kg of materials, and your facility operates 350 days per year. The emissions factor is appropriate for your level of dioxin and dioxin-like compounds control. Estimate the annual release of dioxin and dioxin-like compounds from the stack of your facility.

Solution:

$$R_{\text{air}} = A \times EF$$

Where:

R_{air}	=	annual release of dioxin and dioxin-like compounds to air; (g/yr)
A	=	material processed annually; (kg/yr)
EF	=	dioxin and dioxin-like compounds emissions factor; (ng/kg)
R_{air}	=	$(25,000 \text{ kg materials/day}) \times (350 \text{ days/year}) \times (10 \text{ ng D\&DLC/kg materials})$ $\times (g/10^9 \text{ ng})$
R_{air}	=	0.09 g dioxin and dioxin-like compounds/year

Example 5: Estimating Water Releases

Your facility discharges 100 million gallons per day of treated wastewater into surface water. The emissions factor you have found to be most appropriate for your facility is 10 pg dioxin and dioxin-like compounds per liter of wastewater discharged. The emissions factor reflects the level of dioxin and dioxin-like compounds control that is occurring at your facility. Your facility operates 365 days each year. Estimate the annual release of dioxin and dioxin-like compounds to surface water.

$$R_{\text{water}} = (100 \times 10^6 \text{ gal wastewater/day}) \times (3.78 \text{ L/gal}) \times (365 \text{ days/yr}) \times (10 \text{ pg D\&DLC/L wastewater})$$
$$\times (g/10^{12} \text{ pg})$$

$$R_{\text{water}} = 1.4 \text{ g dioxin and dioxin-like compounds/yr}$$

Example 6: Estimating Releases to Land

In the example above, the wastewater treatment plant process generates 1 kg of dry sludge per 5000 L of wastewater treated. The wastewater treatment process removes 50% of the dioxin and dioxin-like compounds from the wastewater prior to discharging wastewater into surface water. All of the sludge generated at your facility is placed in an on-site RCRA Subtitle C landfill. Calculate how much dioxin and dioxin-like compounds are released to land at your facility.

Step 1. Determine the amount of sludge generated each day at your facility.

Equation 11

Sludge generated = (sludge generation rate per L wastewater) × (wastewater per day)

Sludge generated = (1 kg sludge/5000 L wastewater) × (3.78 × 10⁸ L wastewater/day)

Sludge generated = 7.56 × 10⁴ kg/day

Step 2. Estimate the Emissions Factor (EF) for dioxin and dioxin-like compounds in the sludge

If it is assumed that all the dioxin and dioxin-like compounds that are removed from the wastewater during the treatment process are contained in the sludge generated from the wastewater treatment process, then the EF for sludge can be calculated as a function of dioxin and dioxin-like compounds removal efficiency from the wastewater. Thus the EF for dioxin and dioxin-like compounds in wastewater times the removal efficiency gives an approximate indication of the dioxin and dioxin-like compounds EF for sludge at your facility. In the following calculation, assume the density of sludge = 500 g/L.

Equation 12

EF_{sludge} = [EF_{wastewater} × (1 – fraction D&DLC removed)] × (density of sludge) × (units conversion factors)

EF_{sludge} = [(10 pg D&DLC/L wastewater) × (1 – 0.5)] × (1 L/500 g) × (10³ g/kg)

EF_{sludge} = 10 pg dioxin and dioxin-like compounds/kg

Step 3. Calculate the annual release of dioxin and dioxin-like compounds to land

Equation 13

R_{land} = (quantity sludge/day) × (EF_{sludge}) × (operating days/year)

R_{land} = (7.56 × 10⁴ kg sludge/day) × (10 pg D&DLC/kg sludge) × (g/10¹² pg) × (365 days/year)

R_{land} = 3 × 10⁻⁴ g dioxin and dioxin-like compounds/year

SECTION 4.0 FACILITY-SPECIFIC EPA DEFAULT EMISSIONS FACTORS

EPA is providing default emissions factors for facilities to use, at their discretion, in reporting annual releases and other waste management quantities of dioxin and dioxin-like compounds. You are encouraged, however, to use site-specific information on releases from your facility. EPA recognizes that emissions and environmental release data are not available in most cases. This guidance is providing a series of ‘look-up’ tables to assist you in meeting the requirements of annually reporting releases of dioxin and dioxin-like compounds. Information is limited to those source categories for which EPA believes sufficient information is available to develop default emissions factors that can be used to make reasonable estimations of releases. The documentation for the derivation of the emissions factors can be found in three EPA references:

- *EPA’s Database of Sources of Environmental Releases of Dioxin-Like Compounds in the United States*, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-98/002B, September, 2000.
- *An Inventory of Sources of Dioxin in the U.S. for the Years 1987, 1995, and 2000* (Final, Nov 2006). U.S. Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC 20460, EPA/600/P-03/002F.
- *Estimating Exposure to Dioxin-Like Compounds; Volume 2: Sources of Dioxin-Like Compounds in the United States*, EPA/600/)-00/001, Draft Final, September, 2000.

The most recent versions of the first two documents above can be found at:

<https://www.epa.gov/dioxin/inventory-dioxin-sources-and-environmental-releases>

In applying these default emissions factors, you are encouraged to read the summary description provided for the facilities that were used to derive the default emissions factors. Facilities should use those emissions factors that match as closely as practical the class type and pollution control systems of your facility. Although EPA’s default emissions factors are arithmetic averages of environmental releases from tested facilities, EPA recognizes that these tested facilities may not be an ideal match to your facility. The decision to use EPA default emissions factors is best left to the operator of the facility. This guidance is intentionally made to be flexible in the use and selection of emissions of dioxin and dioxin-like compounds that are most representative of emissions from your facility. All of the emissions factors contained in the tables in this section are for controlled conditions.

In all of the emissions factors tables the emissions factor for the dioxin and dioxin-like compounds category is equal to the sum of the emissions factors for the 7 dibenzo-p-dioxins (CDDs) covered by the category and the 10 dibenzofurans (CDFs) covered by the category. Thus,

Equation 14

$$\sum \text{Dioxin and dioxin-like compounds} = \sum \text{CDD} + \sum \text{CDF}$$

Section 4.1 Pulp and Paper Mills and Lumber and Wood Products

4.1.1 Applicability

The following SIC Codes are included within this category (a crosswalk with NAICS codes is available at: <https://www.census.gov/eos/www/naics/concordances/concordances.html>):

- I. *SIC Code 2611 Pulp Mills*: Establishments primarily engaged in manufacturing pulp from wood or from other materials, such as rags, lintens, wastepaper, and straw. Establishments engaged in

integrated logging and pulp mill operations are classified according to the primary products shipped. Establishments engaged in integrated operations of producing pulp and manufacturing paper, paperboard, or products thereof are classified in Industry 2621 if primarily shipping paper or paper products; in Industry 2631 if primarily shipping paperboard or paperboard products; and in Industry 2611 if primarily shipping pulp.

- II. *2621 Paper Mills*: Establishments primarily engaged in manufacturing paper from woodpulp and other fiber pulp, and which may also manufacture converted paper products. Establishments primarily engaged in integrated operations of producing pulp and manufacturing paper are included in this industry if primarily shipping paper or paper products. Establishments primarily engaged in manufacturing converted paper products from purchased paper stock are classified in Industry Group 265 or Industry Group 267.
- III. *2400 Lumber and Wood Products, Except Furniture*: Establishments primarily engaged in cutting timber and pulpwood; merchant sawmills, lath mills, shingle mills, cooperage stock mills, planing mills, and plywood mills and veneer mills engaged in producing lumber and wood basic materials. Also included within this SIC code are establishments engaged in manufacturing finished articles made entirely or mainly of wood or related materials. Major Group 24 includes Industry Groups 241, 242, 243, 244, 245, and 249. Furniture and office and store fixtures are classified in Major Group 25. Woodworking in connection with construction, in the nature of reconditions and repair, or performed to individual order, is classified in nonmanufacturing industries.

- Industry Group 241

- 2411 Logging

- Industry Group 242

- 2421 Sawmills and Planing Mills

- 2431 Millwork

- 2434 Wood Kitchen Cabinets

- 2435 Hardwood Veneer and Plywood

- 2436 Softwood Veneer and Plywood

- Industry Group 244

- 2441 Nailed and Lock Corner Wood Boxes and Shook

- 2448 Wood Pallets and Skids

- 2449 Wood Containers

- Industry Group 245

- 2451 Mobile Homes

- 2452 Prefabricated Wood Buildings and Components

- Industry Group 249

- 2491 Wood Preserving

- 2493 Reconstituted Wood Products

- 2499 Wood Products

4.1.2 Emissions Factors for Releases to Water from Bleached Chemical Pulp Mills

On April 15, 1998, and August 7, 1998, EPA promulgated final effluent standards (Federal Register, 1998) under the Clean Water Act for pulp and paper mills (63 FR 18504-18751 and 63 FR 42238-42240). Mills subject to regulation are pulp mills and integrated mills (mills that manufacture pulp and paper/paperboard), that chemically pulp wood fiber (using kraft, sulfite, soda, or semi-chemical methods); that produce pulp secondary fiber; pulp non-woody fiber; and mechanically pulp wood fiber. The regulations established dioxin discharge limits for bleached chemical pulp mills. In reporting releases of dioxin and dioxin-like compounds to surface waters, the facility may use the EPA default emissions factors in Table 4-1, which were developed for bleached chemical pulp mills. The data were generated at a series of eight bleached chemical pulp mills prior to promulgation of the effluent standards.

Table 4-1: Average Emissions Factors (pg/L) for Estimating Wastewater Discharges of Dioxin and Dioxin-like Compounds into Surface Water from Bleached Chemical Pulp Mills

CDD	Emissions Factor (pg/L)	CDF	Emissions Factor (pg/L)
2,3,7,8-TCDD	1.2	2,3,7,8-TCDF	2.3
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0
1,2,3,4,7,8-HxCDD	0	2,3,4,7,8-PeCDF	0
1,2,3,6,7,8-HxCDD	0	1,2,3,4,7,8-HxCDF	0
1,2,3,7,8,9-HxCDD	0	1,2,3,6,7,8-HxCDF	0
1,2,3,4,6,7,8-HpCDD	3.2	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	99.0	2,3,4,6,7,8-HxCDF	0
		1,2,3,4,6,7,8-HpCDF	0
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
∑ CDD	103.4	∑ CDF	2.3
∑ Dioxin and dioxin-like compounds*		105.7	

Source: Gillespie, 1997

* \sum Dioxin and dioxin-like compounds = \sum CDD + \sum CDF

4.1.3 Emissions Factors for Releases to Land from Bleached Chemical Pulp Mills

The conventional wastewater treatment of effluents results in the generation of wastewater sludge. If your facility applies the sludge to land, or places it in a RCRA Subtitle C landfill for disposal, then the default emissions factors for bleached chemical pulp mills in Table 4-2 apply. These emissions factors are based on data from a series of the same bleached chemical pulp mills referenced in Section 4.1.2.

Table 4-2: Average Emissions Factors (ng/kg) for Land Disposal of Dioxin and Dioxin-like Compounds in Wastewater Sludge from Bleached Chemical Pulp Mills

CDD	Emissions Factor (ng/kg)	CDF	Emissions Factor (ng/kg)
2,3,7,8-TCDD	0.8	2,3,7,8-TCDF	6.2
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0
1,2,3,4,7,8-HxCDD	0.5	2,3,4,7,8-PeCDF	0.5
1,2,3,6,7,8-HxCDD	2.3	1,2,3,4,7,8-HxCDF	0
1,2,3,7,8,9-HxCDD	1.6	1,2,3,6,7,8-HxCDF	0
1,2,3,4,6,7,8-HpCDD	41.4	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	445.0	2,3,4,6,7,8-HxCDF	0.5
		1,2,3,4,6,7,8-HpCDF	1.2
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
∑ CDD	491.6	∑ CDF	8.4
∑ Dioxin and dioxin-like compounds*		500	

Source: Gillespie, 1997

* \sum Dioxin and dioxin-like compounds = \sum CDD + \sum CDF

4.1.4 Emissions Factors for Releases to Air from Pulp Mill or Lumber and Wood Products Facilities

Wood waste and bark produced from processing timber at a pulp mill or lumber and wood products facility are burned in the facilities' bark and/or wood-waste boilers (NCASI, 1995). This wood waste can produce CDDs/CDFs during combustion. If your lumber and wood products industry facility burns wood waste and bark, then the default emissions factors in Table 4-3 apply.

Table 4-3: Average Emissions Factors (ng/kg) for Air Releases of Dioxin and Dioxin-like Compounds from the Combustion of Wood Waste and Bark (as fired) at Pulp Mill or Lumber and Wood Product Industry Facility Boilers

CDD	Emissions Factor (ng/kg)	CDF	Emissions Factor (ng/kg)
2,3,7,8-TCDD	0.005	2,3,7,8-TCDF	0.104
1,2,3,7,8-PeCDD	0.005	1,2,3,7,8-PeCDF	0.022
1,2,3,4,7,8-HxCDD	0.012	2,3,4,7,8-PeCDF	0.020
1,2,3,6,7,8-HxCDD	0.050	1,2,3,4,7,8-HxCDF	0.070
1,2,3,7,8,9-HxCDD	0.035	1,2,3,6,7,8-HxCDF	0.043
1,2,3,4,6,7,8-HpCDD	0.300	1,2,3,7,8,9-HxCDF	0.036
1,2,3,4,6,7,8,9-OCDD	1.200	2,3,4,6,7,8-HxCDF	0.004
		1,2,3,4,6,7,8-HpCDF	0.274
		1,2,3,4,7,8,9-HpCDF	0.081
		1,2,3,4,6,7,8,9-OCDF	0.187
∑ CDD	1.6	∑ CDF	0.84
∑ Dioxin and dioxin-like compounds*		2.4	

Source: NCASI (1995)

* \sum Dioxin and dioxin-like compounds = \sum CDD + \sum CDF

Section 4.2 Secondary Smelting and Refining of Nonferrous Metals Section

4.2.1 Applicability

SIC Code 3341, Secondary Smelting and Refining of Nonferrous Metals, include establishments primarily engaged in recovering nonferrous metals and alloys from new and used scrap and or in producing alloys from purchased refined metals (a crosswalk with NAICS codes is available at: <https://www.census.gov/eos/www/naics/concordances/concordances.html>). This industry includes establishments engaged in both the recovery and alloying of precious metals. Plants engaged in the recovery of tin through secondary smelting and refining, as well as by chemical processes, are included in this industry. Establishments primarily engaged in assembling, sorting, and breaking up scrap metal, without smelting and refining, are classified in Wholesale Trade, Industry 5093. Applicable facilities include:

- Aluminum smelting and refining, secondary
- Copper smelting and refining, secondary
- Lead smelting and refining, secondary
- Nonferrous metal smelting and refining, secondary
- Recovering and refining of nonferrous metals
- Secondary refining and smelting of nonferrous metals

4.2.2 Secondary Aluminum Smelters

Stack tests from five secondary aluminum facilities (described below) were used by EPA to derive mean air emissions factors of dioxin and dioxin-like compounds. Secondary aluminum smelters reclaim aluminum from scrap containing aluminum. This recycling involves two processes: pre-cleaning and smelting. Both processes may produce CDD/CDF emissions.

Pre-cleaning processes involve sorting and cleaning scrap to prepare it for smelting. Cleaning processes that may produce CDD/CDF emissions use heat to separate aluminum from contaminants and other metals; these techniques are roasting and sweating. Roasting uses rotary dryers with a temperature high enough to vaporize organic contaminants, but not high enough to melt aluminum. An example of roasting is the delacquering and processing of used beverage cans. Sweating involves heating aluminum-containing scrap metal to a temperature above the melting point of aluminum, but below the melting temperature of other metals such as iron and brass. The melted aluminum trickles down and accumulates in the bottom of the sweat furnace and is periodically removed (U.S. EPA, 1997).

After pre-cleaning, the treated aluminum scrap is smelted and refined. This usually takes place in a reverberatory furnace. Once smelted, flux is added to remove impurities. The melt is "demagged" to reduce the magnesium content of the molten aluminum by the addition of chlorine gas. The molten aluminum is transferred to a holding furnace and alloyed to final specifications (U.S. EPA, 1997).

CDD/CDF emissions to air have been measured at five U.S. secondary aluminum operations. These facilities were tested in 1995. The tests were conducted by EPA in conjunction with the Aluminum Association for the purpose of identifying emission rates from facilities with potentially maximum achievable control technology (MACT)-grade operations and air pollution control device (APCD) equipment.

The first facility tested in 1995 was a top charge melt furnace (Advanced Technology Systems, Inc., 1995). During testing, the charge material to the furnace was specially formatted to contain no oil, paint, coatings, rubber, or plastics (other than incidental amounts). The CDD/CDF emissions from such a clean charge, 0.26 ng toxic equivalents (TEQ)/kg charge material, would be expected to represent the low-end of the normal industry range.

The second facility operates a sweat furnace to pre-clean the scrap and a reverberatory furnace to smelt the pre-cleaned aluminum (U.S. EPA, 1995). Stack emissions are controlled by an afterburner operated at 1,450°F.

The third facility employs a crusher/roasting dryer as a pre-cleaning step followed by a reverberatory furnace (Galson Corporation, 1995). The emissions from the two units are vented separately. The exhaust from the crusher/dryer is treated with an afterburner and a baghouse. The exhaust from the furnace passes through a baghouse with lime injection.

The fourth facility operates a scrap roasting dryer followed by a sidewall reverberatory furnace (Roy Weston, 1996). The emissions from the two units are vented separately. Exhaust from the dryer passes through an afterburner and a lime-coated baghouse. The exhaust from the furnace passes through a lime-coated baghouse.

The fifth facility is a dryer/delacquarer secondary aluminum facility tested by Commonwealth Aluminum Corporation (1995). The results of this test were submitted to EPA as part of the public comments by the industry in association with development of the MACT standard.

Table 4-4 summarizes average default emissions factors (ng/kg scrap aluminum processed) for estimating air releases of dioxin and dioxin-like compounds from secondary aluminum smelters. For the default emissions factor, EPA is recommending 50.41 ng dioxin and dioxin-like compounds emitted per kg of

aluminum scrap processed. This is based on an arithmetic average of the five tested facilities presented in the table. As an alternative to using this default emissions factor, the owner or operator of secondary aluminum facilities may review the individual test reports supporting the development of the table (see references), and, based on good engineering judgment, decide the most appropriate emissions factors for your facility. Defaults are given here in the context of providing an option for estimating air releases from secondary aluminum smelters.

Table 4-4: Average Emissions Factors (ng/kg scrap aluminum processed) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Secondary Aluminum Smelters

Congener	Mean Facility Emissions Factor (ng/kg aluminum processed)					Mean Emissions Factor
	Facility 1 (Ref. 1)	Facility 2 (Ref. 2)	Facility 3 (Ref. 3)	Facility 4 (Ref. 4)	Facility 5 (Ref. 5)	
2,3,7,8-TCDD	ND (0.01)	0.13	0.51	0.40	0.01	0.21
1,2,3,7,8-PeCDD	0.02	0.39	1.19	1.19	0.02	0.56
1,2,3,4,7,8-HxCDD	0.05	0.24	1.35	0.72	0.02	0.48
1,2,3,6,7,8-HxCDD	0.13	0.86	1.52	0.94	0.03	0.70
1,2,3,7,8,9-HxCDD	0.15	1.26	2.51	1.62	0.05	1.12
1,2,3,4,6,7,8-HpCDD	0.51	7.67	2.60	3.49	0.1	2.87
OCDD	0.42	14.97	1.01	NA	NA	5.47
2,3,7,8-TCDF	0.44	0.74	14.20	10.46	0.07	5.18
1,2,3,7,8-PeCDF	0.06	1.51	10.47	12.52	0.08	4.93
2,3,4,7,8-PeCDF	0.17	2.44	11.06	6.98	0.12	4.15
1,2,3,4,7,8-HxCDF	0.32	2.44	21.84	8.14	0.16	6.58
1,2,3,6,7,8-HxCDF	0.11	2.69	7.10	2.74	0.06	2.54
1,2,3,7,8,9-HxCDF	0.02	1.02	0.47	0.14	0.01	0.33
2,3,4,6,7,8-HxCDF	0.30	3.82	7.09	4.30	0.08	3.12
1,2,3,4,6,7,8-HpCDF	0.07	11.39	14.61	3.18	0.17	5.88
1,2,3,4,7,8,9-HpCDF	0.03	5.50	1.21	0.45	0.04	1.45
OCDF	0.30	30.40	3.15	1.23	0.06	7.03
∑ Dioxin and Dioxin-Like Compounds	3.11	87.47	101.89	58.50	1.08	50.41

TEQ calculations assume not-detected values are zero. NA= Not available. ND = Not detected (value in parenthesis is the emission at the detection limit).

Sources:

Ref. 1: Advanced Technology Systems, Inc. (1995)

Ref. 2: U.S. EPA (1995h)

Ref. 3: Galson Corporation (1995)

Ref. 4: Roy Weston, Inc. (1996)

Ref. 5: Commonwealth Aluminum Corp (1995)

See also: *An Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the U.S. for the Years 1987, 1995, and 2000 (Final, Nov 2006)*. U.S. EPA (2006).

4.2.3 Secondary Lead Smelters

The secondary lead smelting industry produces elemental lead through the chemical reduction of lead compounds in a high temperature furnace (1,200° to 1,260°C). Smelting is performed in reverberatory, blast, rotary, or electric furnaces. Blast and reverberatory furnaces are the most common types of smelting furnaces used by the facilities that comprise the current secondary lead smelting industry in the United States (U.S. EPA, 1994b). As of 2011, the total current annual production capacity of the 15 facilities comprising the U.S. lead smelting industry is approximately 1 million metric tons (U.S. EPA, 2011).

Furnace charge materials consist of lead-bearing raw materials, lead-bearing slag and drosses, fluxing agents (blast and rotary furnaces only), and coke. Scrap motor vehicle lead-acid batteries represent about 90 percent of the lead-bearing raw materials at a typical lead smelter. Fluxing agents consist of iron, silica sand, and limestone or soda ash. Coke is used as fuel in blast furnaces and as a reducing agent in reverberatory and rotary furnaces. Organic emissions from co-located blast and reverberatory furnaces are more similar to the emissions of a reverberatory furnace than the emissions of a blast furnace (U.S. EPA, 1994b).

Historically, many lead-acid batteries contained PVC plastic separators between the battery grids. These separators are not removed from the lead-bearing parts of the battery during the battery breaking and separation process. When the PVC is burned in the smelter furnace, the chlorine atoms are released as HCl, Cl₂, and chlorinated hydrocarbons (Federal Register, 1995d). The source of CDD/CDFs at secondary lead smelters is the PVC separator (U.S. EPA, 1995c). In 1990, about 1 percent of scrap batteries processed at lead smelters contained PVC separators. In 1994, less than 0.1 percent of scrap batteries contained PVC separators. This trend is expected to continue because no U.S. manufacturer of lead-acid automotive batteries currently uses PVC in production (U.S. EPA, 1995c; Federal Register, 1995d).

CDD/CDF emissions factors can be estimated for lead smelters based on the results of emission tests performed by EPA at three smelters (a blast furnace, a co-located blast/reverberatory furnace, and a rotary kiln furnace) (U.S. EPA, 1992e; 1995d; 1995e). The air pollution control systems at the three tested facilities consisted of both baghouses and scrubbers. Congener-specific measurements were made at the exit points of both APCD exit points at each facility. Table 4-5 presents the congener emissions factors from the baghouse and the scrubber for each site.

Table 4-5: Average Emissions Factors (ng/kg) for Estimating Annual Releases of Dioxin and Dioxin-Like Compounds from Secondary Lead Smelters

CDD/CDF Congener	Blast Furnace (ng/kg lead produced)		Blast/reverb (ng/kg lead produced)		Rotary kiln (ng/kg lead produced)	
	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>
2,3,7,8-TCDD	2.11	0.25	0.00	0.00	0.10	0.24
1,2,3,7,8-PeCDD	0.99	0.03	0.00	0.00	0.01	0.00
1,2,3,4,7,8-HxCDD	0.43	0.00	0.00	0.00	0.00	0.00
1,2,3,6,7,8-HxCDD	0.99	0.03	0.00	0.00	0.00	0.00
1,2,3,7,8,9-HxCDD	1.55	0.03	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDD	2.06	0.08	0.10	0.06	0.00	0.22
1,2,3,4,6,7,8,9-OCDD	1.40	0.39	0.57	0.55	0.24	2.41
Σ CDD	9.53	0.81	0.67	0.61	0.35	2.87

CDD/CDF Congener	Blast Furnace (ng/kg lead produced)		Blast/reverb (ng/kg lead produced)		Rotary kiln (ng/kg lead produced)	
	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>	<i>before scrubber</i>	<i>after scrubber</i>
2,3,7,8-TCDF	8.73	0.93	1.46	0.49	0.40	1.20
1,2,3,7,8-PeCDF	3.88	0.43	0.24	0.02	0.14	0.40
2,3,4,7,8-PeCDF	6.65	0.36	0.31	0.00	0.14	0.46
1,2,3,4,7,8-HxCDF	5.83	0.37	0.63	0.00	0.11	0.27
1,2,3,6,7,8-HxCDF	1.67	0.11	0.19	0.00	0.02	0.10
1,2,3,7,8,9-HxCDF	0.11	0.00	0.00	0.00	0.04	0.13
2,3,4,6,7,8-HxCDF	2.06	0.11	0.15	0.00	0.00	0.00
1,2,3,4,6,7,8-HpCDF	2.34	0.19	0.48	0.00	0.03	0.13
1,2,3,4,7,8,9-HpCDF	0.63	0.06	0.00	0.00	0.00	0.00
1,2,3,4,6,7,8,9-OCDF	1.39	0.18	0.29	0.00	0.00	0.00
∑ CDF	33.29	2.74	3.75	0.51	0.88	2.69
∑ Dioxin and dioxin-like compounds*	42.82	3.55	4.42	1.12	1.23	5.56

Source: U.S. EPA (2006)

*∑ Dioxin and dioxin-like compounds = ∑ CDD + ∑ CDF

From the reported data, congener-specific CDD/CDF emissions factors (ng/kg lead processed) for each of the three furnace configurations are presented in Table 4-5. The range reflects the presence or absence of a scrubber. Note that calculations using emissions factors before scrubbers would apply towards threshold calculations since this represents amounts that have been manufactured. They can also be used to estimate the amounts that a scrubber has removed and then the amounts removed, depending on how the scrubber material is handled, should be reported in the appropriate section of the Form R.

As discussed earlier in this section, the PVC separators used historically in lead-acid batteries are believed to be the source of the CDD/CDFs observed in emissions from secondary lead smelters. PVC separators are no longer used in the United States in the manufacture of lead-acid batteries, and less than 0.1 percent of the scrap batteries in 1994 contained PVC separators (U.S. EPA, 1995c; Federal Register, 1995c).

4.2.4 Secondary Copper Smelters/Refiners

Secondary copper smelting is part of the scrap copper, brass, and bronze reprocessing industry. Brass is an alloy of copper and zinc; bronze is an alloy of copper and tin. Facilities in this industry fall into three general classifications: secondary smelting, ingot making, and remelting. Similar process equipment may be used at all three types of facilities, so that the distinguishing features are not immediately apparent (U.S. EPA, 1994c).

The feature that distinguishes secondary smelters from ingot makers and remelters is the extent to which pyrometallurgical purification is performed. A typical charge at a secondary smelter may contain from 30 to 98 percent copper. The secondary smelter upgrades the material by reducing the quantity of impurities and alloying materials, thereby increasing the relative concentration of copper.

This degree of purification and separation of the alloying constituents does not occur at ingot makers and remelters. Feed material to a secondary copper smelter is a mixture of copper-bearing scrap comprised of such scrap as tubing, valves, motors, windings, wire, radiators, turnings, mill scrap, printed circuit boards, telephone switching gear, and ammunition casings. Non-scrap items like blast furnace slags and drosses

from ingot makers or remelters may represent a portion of the charge. The secondary smelter operator uses a variety of processes to separate the alloying constituents. Some purify the scrap in the reductive atmosphere of a blast furnace. The charge may be subsequently purified in the oxidizing atmosphere of a converter. Other secondary smelters perform all purification by oxidation in top-blown rotary converters or in reverberatory furnaces (U.S. EPA, 1994c).

The ingot makers blend and melt scrap copper, brass, and bronze of various compositions to produce a specification brass or bronze ingot. When necessary, the ingot makers add ingots of other metals (e.g., zinc or tin) to adjust the metallurgy of the final product. The feed materials for ingot makers contain relatively high amounts of copper. Examples of feed materials include copper tubing, valves, brass and bronze castings, ammunition shell casings, and automobile radiators. “Fire-refined” anode copper or cathode copper may also be charged. Items such as motors, telephone switchboard scrap, circuit board scrap, and purchased slags are not used by ingot makers. The reductive step (melting in a reducing atmosphere, as in a blast furnace) that some secondary smelters employ is not used by ingot makers. Ingot makers do, however, use some of the other types of furnaces used by secondary smelters, including direct-fired converters, reverberatory furnaces, and electric induction furnaces (U.S. EPA, 1994c).

Remelting facilities do not conduct any substantial purification of the incoming feeds. These facilities typically just melt the charge and cast or extrude a product. The feeds to a remelter are generally alloy material of approximately the desired composition of the product (U.S. EPA, 1994c).

In 1991, stack testing of the rotary furnace stack emissions of a secondary smelter located in Alton, Illinois (Chemetco, Inc.) was conducted by Sverdrup Corp. (1991). The Chemetco facility uses four tap down rotary (i.e., oxidizing) furnaces. Furnace process gas emissions are controlled by a primary quencher and a venturi scrubber. The feed is relatively high purity copper scrap containing minimal plastics, if any. The same manufacturing process and APCD equipment were in place in 1987 and 1995 (U.S. EPA, 1994c). This facility operated under oxidizing rather than reducing conditions and processes relatively high purity scrap, the potential for CDD/CDF formation and release is expected to be dramatically different than that of the two tested facilities reported above. The estimated emissions factors derived for this site from the results in Sverdrup (1991) are presented in Table 4-6.

Although little research has been performed to define the CDD/CDF formation mechanism(s) in secondary copper smelting operations, two general observations have been made (Buekens et al., 1997). The presence of chlorinated plastics in copper scraps used as feed to the smelters is believed to increase the CDD/CDF formation. Second, the reducing or pyrolytic conditions in blast furnaces can lead to high CDD/CDF concentrations in the furnace process gases.

It should be noted that a significant amount of scrap copper is consumed by other segments of the copper industry. In 2015, brass mills and wire-rod mills consumed 672,000 metric tons of copper- base scrap; foundries, chemical plants and miscellaneous users consumed 55,800 metric tons (U.S. Geological Survey, 2017). As noted above, these facilities generally do not conduct any significant purification of the scrap. Rather, the scrap consumed is already of alloy quality and processes employed typically involve only melting, casting, and extruding. Thus, the potential for formation of CDDs/CDFs is expected to be much less than the potential during secondary smelting operations.

Table 4-6: CDD/CDF Emissions Factors (ng/kg scrap feed) for Secondary Copper Smelters

CDD Congener	Emissions Factor (ng/kg scrap feed)	CDF Congener	Emissions Factor (ng/kg scrap feed)
2,3,7,8-TCDD	ND (0.05)	2,3,7,8-TCDF	2.11
1,2,3,7,8-PeCDD	0.21	1,2,3,7,8-PeCDF	1.47
1,2,3,4,7,8-HxCDD	0.39	2,3,4,7,8-PeCDF	2.63

CDD Congener	Emissions Factor (ng/kg scrap feed)	CDF Congener	Emissions Factor (ng/kg scrap feed)
1,2,3,6,7,8-HxCDD	0.70	1,2,3,4,7,8-HxCDF	7.30
1,2,3,7,8,9-HxCDD	1.26	1,2,3,6,7,8-HxCDF	2.15
1,2,3,4,6,7,8-HpCDD	8.95	1,2,3,7,8,9-HxCDF	4.06
1,2,3,4,6,7,8,9-OCDD	22.45	2,3,4,6,7,8-HxCDF	0.27
		1,2,3,4,6,7,8-HpCDF	11.48
		1,2,3,4,7,8,9-HpCDF	2.74
		1,2,3,4,6,7,8,9-OCDF	21.61
∑ CDD	33.96	∑ CDF	55.82
∑ Dioxin and dioxin-like compounds*		89.78	

Source: Sverdrup (1991).

* \sum Dioxin and dioxin-like compounds = \sum CDD + \sum CDF

ND = Not detected (value in parenthesis is the emission at the detection limit).

Table 4-6 is a listing of CDD/CDF default emissions factors for secondary copper smelters. In choosing the appropriate emissions factor, the owner/operator is encouraged to exercise good engineering judgment to appropriately select the most suitable emissions factors. Such judgment requires first-hand knowledge of your process. EPA believes that the most appropriate default emissions factors are those derived from the stack testing of the Chemetco Smelting Facility as shown in Table 4-6. This is because the state-of-the-art involved in secondary copper smelting calls for the mechanical removal of plastic material prior to smelting and refining, and to use copper-laden scrap that is relatively free of organic contamination. Therefore, if your facility processes copper scrap containing a relatively high amount of plastics, then the emissions factors listed in Table 4-6 are not appropriate to use as default emissions factors. Emissions factors for a second facility, Franklin Smelting and Refining Co, that includes plastic waste in its smelting feed (AGES, 1992) are published elsewhere (U.S. EPA, 2006).

Section 4.3 Cement Kilns Section

4.3.1 Applicability

Kilns used in the pyroprocessing of Portland Cement clinker as defined in SIC Code 3241 (a crosswalk with NAICS codes is available at:

<https://www.census.gov/eos/www/naics/concordances/concordances.html>).

4.3.2 Summary Description / Air Emissions Factors

In the United States, the primary cement product is called Portland cement. Portland cement is a fine, grayish powder consisting of a mixture of four basic materials: limestone, silica, alumina, and iron compounds. Cement production involves heating (pyroprocessing) the raw materials (known as raw meal) to a very high temperature in a rotary (rotating) kiln to induce chemical reactions that produce a fused material called clinker. The cement clinker is further ground into a fine powder and mixed with gypsum to form the Portland cement.

The cement kiln is a large, rotating steel cylindrical furnace lined with refractory material. The kiln is aligned on a slight angle, usually a slope of 3°-6°. This allows for the materials to pass through the kiln by gravity. The upper end of the kiln is known as the cold or back end and this is where the raw materials, or meal, is generally fed into the kiln. The lower end of the kiln is known as the “hot” end. The hot end is where the combustion of primary fuels (coal, petroleum coke, natural gas, etc.) transpires to produce a high temperature.

The cement kiln is operated in a counter-current configuration. This means that the hot combustion gases are convected up through the kiln while the raw materials are passing down toward the lower end. The rotation of the kiln induces mixing and the forward progress of mixed materials. As the meal moves through the cement kiln and is heated by the hot combustion gases, water is vaporized and pyroprocessing of materials occurs.

When operating, the cement kiln can be viewed as consisting of three temperature zones necessary to produce clinker. Zone 1 is at the upper end of the kiln where the raw meal is added. Temperatures in this zone typically range from ambient up to 600°C. In this area of the kiln, moisture is evaporated from the raw meal. The second thermal zone is known as the calcining zone. Calcining occurs when the hot combustion gases from the combustion of primary fuels dissociates calcium carbonate from the limestone to form calcium oxide. In this region of the kiln, temperatures are in a range of 600°C to 900°C. The third region of the kiln is known as the burning or sintering zone. The burning zone is the hottest region of the kiln. In this region, temperatures in excess of 1,500°C induce the calcium oxide to react with silicates, iron and aluminum in the raw materials to form clinker. The formation of clinker actually occurs near the lower end of the kiln (close to the combustion of primary fuel) where temperatures are the hottest. The chemical reactions that occur here are referred to as pyroprocessing.

The clinker that leaves the hot end of the kiln is a gray-colored, glass-hard material comprised of dicalcium silicate, tricalcium silicate, calcium aluminates, and tetracalcium aluminoferrite. At this point, the clinker has a temperature of about 1,100°C. The hot clinker is then transferred into the clinker cooler. Once cooled, the clinker is ground into a fine powder and mixed with gypsum to produce Portland cement.

Cement kilns are either wet or dry processes. In the wet process, the raw materials are ground and mixed with water to form a slurry. The meal-water slurry is fed into the kiln through a pump. A greater amount of heat energy is needed in the wet process to evaporate the additional water.

In the dry process, the raw meal is ground to a fine, dry powder prior to entering the kiln. There are three types of dry processes: long-dry, preheater, and preheater/precalciner. Long dry kilns are similar to wet kilns, with the exception of the dry state of the raw materials. In preheater kilns, the raw material is heated prior to entering the kiln. This allows for a shorter kiln and lower combustion fuel use. Precalciners take this a step further by heating the raw feed to a level at which partial calcination takes place prior to entering the kiln. A typical preheater/precalciner kiln consists of a vertical tower containing a series of cyclone-type vessels. Raw meal is added at the top of the tower, and hot kiln exhaust flue gases from the kiln operation are used to preheat the meal prior to being introduced into the kiln. Preheating and precalcining the meal has the advantage of lowering fuel consumption of the kiln.

There are also two primary types of air pollution control devices (APCDs) for the kiln: fabric filters and electrostatic precipitators (ESPs). Either of these can be used on any of the four process types.

Cement manufacturing is an energy intensive manufacturing process. Fossil fuels are the primary sources of fuel. In addition, 15 cement plants in the U.S. currently supplement their fuel needs through the use of energy-bearing hazardous waste. For the last ten years, these facilities have been regulated by the Resource Conservation and Recovery Act's (RCRA) Boiler and Industrial Furnace (BIF) rules. As a result, a database has been developed characterizing emissions from these facilities. Testing and additional studies have contributed significantly to our understanding of dioxin formation in cement plants.

In developing Maximum Achievable Control Technology (MACT) standards for cement plants, EPA "considered both hazardous waste burning cement kiln and non-hazardous waste burning cement kiln data together because both data sets are adequately representative of general dioxin/furan behavior and control in either type of kiln. This similarity is based on our engineering judgement that hazardous waste burning

does not have an impact on dioxin/furan formation, dioxin/furan is formed post-combustion.” (See 64 FR 52876) APCD air inlet temperature (and the time that the air takes to enter the device) in conjunction with other site-specific elements is the determining factor.

On June 14, 1999, EPA published a National Emission Standard for Hazardous Air Pollutants (NESHAP) for the Portland cement industry in the Federal Register (64 FR 31898). In addition, on September 30, 2000, EPA published a NESHAP for hazardous waste combustors (including cement kilns that recover energy from hazardous wastes) in the Federal Register (64 FR 52828). These rules require, among other things, that all cement plants periodically conduct dioxin/furan testing.

Because only one test report applicable to reference year 2000 was located for a cement kiln burning nonhazardous waste (Bell, 1999), and the results from the tests were similar to the results reported by EPA in 1996 (U.S. EPA, 1996), EPA combined the results from the two data sets (U.S. EPA, 2006). The congener-specific emissions factors are presented in Table 4-7. As an operator/owner of a facility, you may elect to use more current information in the development of an emissions factor, or you may elect to use the EPA default. If you elect to use more current emissions factors, then you will be using Approach 2 (Section 2.1.2) to derive your emission estimate appropriate for your facility.

Table 4-7: Average Emissions Factors (ng/kg clinker) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Cement Kilns *Not Combusting Hazardous Waste as Supplemental Fuel*

CDD Congener	Emissions Factor (ng/kg clinker)	CDF Congener	Emissions Factor (ng/kg clinker)
2,3,7,8-TCDD	0.01	2,3,7,8-TCDF	0.73
1,2,3,7,8-PeCDD	0.03	1,2,3,7,8-PeCDF	0.10
1,2,3,4,7,8-HxCDD	0.03	2,3,4,7,8-PeCDF	0.22
1,2,3,6,7,8-HxCDD	0.04	1,2,3,4,7,8-HxCDF	0.17
1,2,3,7,8,9-HxCDD	0.04	1,2,3,6,7,8-HxCDF	0.05
1,2,3,4,6,7,8-HpCDD	0.39	1,2,3,7,8,9-HxCDF	0.01
1,2,3,4,6,7,8,9-OCDD	0.64	2,3,4,6,7,8-HxCDF	0.08
		1,2,3,4,6,7,8-HpCDF	0.13
		1,2,3,4,7,8,9-HpCDF	0.00
		1,2,3,4,6,7,8,9-OCDF	0.22
∑ CDD	1.18	∑ CDF	1.71
∑ Dioxin and dioxin-like compounds*		2.89	

Source: U.S. EPA (2006)

*∑ Dioxin and dioxin-like compounds = ∑ CDD + ∑ CDF

Section 4.4 Utilities

4.4.1 Applicability

This applies to SIC Codes 4911, 4931, and 4939 Electric Services (a crosswalk with NAICS codes is available at: <https://www.census.gov/eos/www/naics/concordances/concordances.html>). This guidance is for electric power utility boilers burning coal, wood and oil for the expressed purpose of producing steam to operate a steam generator, which, in turn, generates electricity.

4.4.2 Description/Emissions Factors for Coal-Fired Electric Utility Boilers

In 1993, the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI) collaborated on assessing stack emissions of hazardous air pollutants at coal-fired power plants. As part of this project, CDD/CDF stack emissions were measured at seven U.S. coal-fired power plants (utility boilers). The levels reported for individual 2,3,7,8-substituted congeners were typically not detected or very low (i.e., 0.033 ng/Nm³).

OCDF and 2,3,7,8-TCDF were the most frequently detected congeners. Variation in emissions between plants could not be attributed by Riggs et al. (1995) to any specific fuel or operational characteristic. The Electric Power Research Institute (EPRI) has published the results of the DOE/EPRI cooperative testing of a total of eleven plants (EPRI, 1994). The average congener emissions factors derived from this eleven-facility data set, as reported in EPRI (1994), are presented in Table 4-8.

Table 4-8: Average Emissions Factors (ng/kg coal combusted) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Coal-Fired Electric Utility Boilers

CDD Congener	Emissions Factor (ng/kg coal combusted)	CDF Congener	Emissions Factor (ng/kg coal combusted)
2,3,7,8-TCDD	0.005	2,3,7,8-TCDF	0.109
1,2,3,7,8-PeCDD	0	1,2,3,7,8-PeCDF	0.007
1,2,3,4,7,8-HxCDD	0	2,3,4,7,8-PeCDF	0.074
1,2,3,6,7,8-HxCDD	0.004	1,2,3,4,7,8-HxCDF	0.098
1,2,3,7,8,9-HxCDD	0.004	1,2,3,6,7,8-HxCDF	0.014
1,2,3,4,6,7,8-HpCDD	0.216	1,2,3,7,8,9-HxCDF	0.013
1,2,3,4,6,7,8,9-OCDD	0.513	2,3,4,6,7,8-HxCDF	0.043
		1,2,3,4,6,7,8-HpCDF	0.354
		1,2,3,4,7,8,9-HpCDF	0.087
		1,2,3,4,6,7,8,9-OCDF	0.158
∑ CDD	0.74	∑ CDF	0.96
∑ Dioxin and dioxin-like compounds*		1.70	

Source: EPRI (1994)-11 facility data set

*∑ Dioxin and dioxin-like compounds = ∑CDDs + ∑CDFs. Assumes non-detects = 0.

4.4.3 Description/Emissions Factors for Oil-Fired Electric Utility Boilers

Preliminary CDD/CDF emissions factors for oil-fired utility boilers developed from boiler tests conducted over the past several years are reported in U.S. EPA (1995c). In 1993, the Electric Power Research Institute (EPRI) sponsored a project to gather information of consistent quality on power plant emissions. This project, the Field Chemical Emissions Measurement (FCEM) project, included testing of two cold side ESP-equipped oil-fired power plants for CDD/CDF emissions (EPRI, 1994). Table 4-9 presents CDD/CDF congener-specific emissions factors for oil-fired utility boilers.

Table 4-9: Average Emissions Factors (pg/L oil combusted) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Oil-Fired Utility Boilers

CDD Congener	Emissions Factor (pg/L oil combusted)	CDF Congener	Emissions Factor (pg/L oil combusted)
2,3,7,8-TCDD	0	2,3,7,8-TCDF	0
1,2,3,7,8-PeCDD	24.7	1,2,3,7,8-PeCDF	64.1

CDD Congener	Emissions Factor (pg/L oil combusted)	CDF Congener	Emissions Factor (pg/L oil combusted)
1,2,3,4,7,8-HxCDD	63.3	2,3,4,7,8-PeCDF	49.3
1,2,3,6,7,8-HxCDD	65.8	1,2,3,4,7,8-HxCDF	76.5
1,2,3,7,8,9-HxCDD	79.7	1,2,3,6,7,8-HxCDF	35.4
1,2,3,4,6,7,8-HpCDD	477	1,2,3,7,8,9-HxCDF	0
1,2,3,4,6,7,8,9-OCDD	2055	2,3,4,6,7,8-HxCDF	23.8
		1,2,3,4,6,7,8-HpCDF	164
		1,2,3,4,7,8,9-HpCDF	0
		1,2,3,4,6,7,8,9-OCDF	0
∑ CDD	2,765.5	∑ CDF	413.1
∑ Dioxin and dioxin-like compounds*		3,178.6	

Source: EPRI (1994) - based on two cold side ESP-equipped power plants.

Calculation of emissions factors assumes density of oil of 0.87 kg/L.

*∑ Dioxin and dioxin-like compounds = ∑ CDD + ∑ CDF

4.4.4 Description/Emissions Factors for Wood-Fired Electric Utility Boilers

Congener-specific measurements of CDDs/CDFs in stack emissions from wood-fired electric utility boilers were measured by the California Air Resources Board at four facilities in 1988 (CARB, 1990b; CARB, 1990e; CARB, 1990f; CARB, 1990g). In CARB (1990b), CDDs/CDFs were measured in the emissions from a quad-cell wood-fired boiler used to generate electricity. The fuel consisted of coarse wood waste and sawdust from non-industrial logging operations. The exhaust gas passed through a multicyclone before entering the stack. In CARB (1990e), CDDs/CDFs were measured in the emissions from two spreader stoker wood-fired boilers operated in parallel by an electric utility for generating electricity. The exhaust gas stream from each boiler is passed through a dedicated electrostatic precipitator (ESP) after which the gas streams are combined and emitted to the atmosphere through a common stack. Stack tests were conducted both when the facility burned fuels allowed by existing permits and when the facility burned a mixture of permitted fuel supplemented by urban wood waste at a ratio of 70:30. In CARB (1990f), CDDs/CDFs were measured in the emissions from a twin fluidized bed combustors designed to burn wood chips for the generation of electricity. The APCD system consisted of ammonia injection for controlling nitrogen oxides, and a multicyclone and electrostatic precipitator for controlling particulate matter. During testing, the facility burned wood wastes and agricultural wastes allowed by existing permits.

In CARB (1990g), CDDs/CDFs were measured in the emissions from a quad-cell wood-fired boiler. During testing, the fuel consisted of wood chips and bark. The flue gases passed through a multicyclone and an ESP before entering the stack. In NCASI (1995), stack emission test results for five boilers burning bark or wood residues were provided. Each passed gasses through a multicyclone or ESP. The mean of the emissions factors derived from the nine studies is used in Table 4-10 as most representative of industrial wood combustion.

Table 4-10: Average Emissions Factors (ng/kg wood) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Wood-Fired Electric Utility Boilers

CDD Congener	Emissions Factor (ng/kg wood)	CDF Congener	Emissions Factor (ng/kg wood)
2,3,7,8-TCDD	0.04	2,3,7,8-TCDF	0.684
1,2,3,7,8-PeCDD	0.079	1,2,3,7,8-PeCDF	0.406

CDD Congener	Emissions Factor (ng/kg wood)	CDF Congener	Emissions Factor (ng/kg wood)
1,2,3,4,7,8-HxCDD	0.115	2,3,4,7,8-PeCDF	0.389
1,2,3,6,7,8-HxCDD	0.138	1,2,3,4,7,8-HxCDF	0.375
1,2,3,7,8,9-HxCDD	0.321	1,2,3,6,7,8-HxCDF	0.418
1,2,3,4,6,7,8-HpCDD	0.745	1,2,3,7,8,9-HxCDF	0.178
1,2,3,4,6,7,8,9-OCDD	3.329	2,3,4,6,7,8-HxCDF	0.192
		1,2,3,4,6,7,8-HpCDF	1.062
		1,2,3,4,7,8,9-HpCDF	0.113
		1,2,3,4,6,7,8,9-OCDF	0.674
∑ CDD	4.767	∑ CDF	4.491
∑ Dioxin and dioxin-like compounds*		9.258	

Source: US EPA (2006)

*∑ Dioxin and dioxin-like compounds = ∑ CDD + ∑ CDF

Section 4.5 Hazardous Waste Combustion Section

4.5.1 Applicability

This category applies to SIC Code 4953. In particular, this guidance is applicable to commercial hazardous waste combustors (RCRA Permitted Facilities), and to boilers and industrial furnaces (BIFs) burning hazardous waste. This also includes cement kilns burning hazardous waste as supplemental fuel (SIC Code 3241), and Utilities (SIC Codes 4911, 4931, and 4939) that burn hazardous waste as supplemental fuel in the boiler. A crosswalk with NAICS codes is available at:

<https://www.census.gov/eos/www/naics/concordances/concordances.html>.

4.5.2 Commercial Boilers and Industrial Furnaces Burning Hazardous Waste (Other than Cement Kilns)

In 1991, EPA established rules that allow the combustion of some liquid hazardous waste in industrial boilers and furnaces (Federal Register, 1991). These facilities typically burn oil or coal for the primary purpose of generating electricity. Liquid hazardous waste can only be burned as supplemental (auxiliary) fuel, and usage is limited by the rule to no more than 5 percent of the primary fuels. These facilities typically use an atomizer to inject the waste as droplets into the combustion chamber and are equipped with particulate and acid gas emission controls. In general, they are sophisticated, well-controlled facilities that achieve good combustion. Emissions factors for hazardous waste incinerators and boilers can be found in Table 4-12 (U.S. EPA, 2006).

4.5.3 Cement Kilns Burning Hazardous Waste as Supplemental Fuel

The high temperatures achieved in cement kilns make cement kilns an efficient technology for combusting hazardous waste as supplemental fuel. Sustaining the relatively high combustion temperatures (1,100°C to 1,500°C) that are needed to form cement clinker requires the burning of a fuel with a high energy output. Therefore, coal or petroleum coke is typically used as the primary fuel source. Because much of the cost of operating the cement kiln at high temperatures is associated with the consumption of fossil fuels, some cement kiln operators have elected to burn hazardous liquid and solid waste as supplemental fuel. Facilities that burn hazardous waste for energy recovery must comply with both RCRA and CAA regulations that specifically regulate this practice. Currently about 75 percent of the primary fuel is coal. Organic hazardous waste may have a similar energy output as coal (9,000 to 12,000 Btu/lb for coal). The strategy of combusting the waste as supplemental fuel is to off- set the amount of

coal/coke that is purchased and burned by the kiln. Much of the high energy and ignitable wastes are primarily comprised of such diverse substances as waste oils, spent organic solvents, sludges from the paint and coatings industry, waste paints and coatings from the auto and truck assembly plants, and sludges from the petroleum refining industry (Greer et al., 1992). The conditions inherent in the cement kiln mimic conditions of hazardous waste incineration. For example, the gas residence time in the burning zone is typically three seconds while at temperatures in excess of 1,500°C (Greer et al., 1992). In addition, trial burns have consistently shown that 99.99 to 99.9999 percent destruction and removal efficiencies for the very stable organic wastes can be achieved in cement kilns (Greer et al., 1992). Although the combustion of hazardous waste as supplemental or substitute fuel does have apparent advantages, only 16 percent of the Portland cement kilns (34 of the 212 kilns) combusted hazardous waste in 1995 (Federal Register, 1996b), as of 2000 only 15 plants (32 kilns) were burning hazardous waste. Other types of supplemental fuel used by these facilities include automobile tires, used motor oil, and sawdust, and scrap wood chips. The method of introducing liquid and solid hazardous waste into the kiln is a key factor to the complete consumption of the waste during the combustion of the primary fuel. Liquid hazardous waste is either injected separately or blended with the primary fuel (coal). Solid waste is mixed and burned along with the primary fuel. The pyroprocessing of raw meal in a cement kiln produces cement as fine particulates. At some facilities, cement kiln dust, which is an even finer particulate, is collected and controlled with fabric filters and/or electrostatic precipitators. Acid gases such as SO₂ can be formed during pyroprocessing of the sulfur-laden minerals, but the minerals have high alkalinity which neutralizes SO₂ gases.

Emissions factors (ng/kg clinker produced) for Portland cement kilns burning hazardous waste as supplemental fuel are displayed in Table 4-11. These emissions factors were developed from stack testing of CDD/CDF emissions from eleven cement kilns burning hazardous waste. The majority of stack emissions data from cement kilns burning hazardous waste were derived during trial burns and may overestimate the CDD/CDF emissions that most kilns achieve during normal operations.

The emissions factors in Table 4-11 were derived from facilities that were stack tested in 1998 and may not reflect current regulatory requirements. In 1999, EPA promulgated final standards for the stack emission limits of dioxin and dioxin-like compounds from hazardous waste combustion facilities (64 FR 52828 - 53077; Final Standards for Hazardous Air Pollutants For Hazardous Waste Combustors; Final Rule; September 30, 1999). The promulgated regulations require periodic stack sampling for dioxin-like compounds for all cement kilns burning hazardous waste. The owner/operator of such facilities is encouraged to use actual facility-specific emissions data (i.e., Approach 1) in lieu of EPA's default emissions factors. Such data are the most representative and best data to use in estimating annual releases of dioxin-like compounds.

Table 4-11: Average Emissions Factors (ng per dscm) for Estimating Air Releases of Dioxin and Dioxin-Like Compounds from Cement Kilns Combusting Hazardous Waste as Supplemental Fuel

Facility	2378-TCDD	12378-PeCDD	123478-HxCDD	123678-HxCDD	12378-HxCDD	1234678-HpCDD	OCDD			
A	0.096	0.089	0.144	0.258	0.206	2.162	0.461			
B	0.028	0.014	0.009	0.008	0.010	0.043	0.459			
C	0.005	0.011	0.014	0.016	0.559	0.155	3.325			
D	0.310	0.496	0.709	1.381	1.893	6.011	0.784			
E	0.005	0.010	0.010	0.012	0.006	0.068	0.033			
F	0.007	0.009	0.006	0.012	0.013	0.057	0.201			
G	0.053	0.327	0.536	0.832	0.812	5.366	1.752			
H	0.026	0.039	0.054	0.078	0.048	0.430	0.140			
I	0.067	1.191	1.385	1.875	2.697	9.971	1.542			
J	0.035	0.041	0.048	0.047	0.044	0.216	0.091			
K	0.016	0.019	0.022	0.023	0.018	0.064	0.154			
Mean emissions factor (ng/dscm)	0.059	0.204	0.267	0.413	0.573	2.231	0.813			
Facility	2378-TCDF	12378-PeDF	23478-PeCDF	123478-HxCDF	123678-HxCDF	123789-HxCDF	234678-HxCDF	1234678-HpCDF	1234789-HpCDF	OCDF
A	1.080	0.078	0.183	0.098	0.043	0.031	0.065	0.051	0.048	0.116
B	0.755	0.070	0.093	0.034	0.019	0.007	0.025	0.006	0.008	0.029
C	0.380	0.035	0.067	0.039	0.017	0.003	0.027	0.026	0.006	0.021
D	1.604	1.050	2.353	2.024	1.029	0.316	1.441	0.946	0.256	0.141
E	0.111	0.005	0.012	0.008	0.004	0.005	0.006	0.009	0.010	0.039
F	0.011	0.005	0.010	0.011	0.005	0.002	0.006	0.010	0.003	0.008
G	0.562	0.654	1.790	1.366	0.533	0.115	1.168	0.609	0.192	0.119
H	0.072	0.014	0.054	0.022	0.015	0.003	0.011	0.009	0.006	0.008
I	0.572	0.239	0.570	0.450	0.208	0.060	0.344	0.208	0.066	0.060
J	0.239	0.223	0.226	0.182	0.103	0.023	0.085	0.185	0.043	0.095
K	0.462	0.121	0.133	0.078	0.031	0.017	0.032	0.050	0.024	0.106
Mean emissions factor (ng/dscm)	0.532	0.227	0.499	0.392	0.182	0.053	0.292	0.192	0.060	0.067
Σ Dioxin and dioxin-like compounds:	7.06 ng per dry standard cubic meter of stack gas									

The emissions factors in Table 4-11 are in units of nanogram dioxin-like compound per dry standard cubic meter (at standard temperature and pressure and adjusted to 7% oxygen) of stack gas flow. This unit is a concentration of dioxin-like compounds measured in the stack gases. The facilities listed in Table 4-11 are cement kilns burning hazardous waste, and the emissions factors (expressed on a concentration basis) are the average of multiple “runs” at the same facility. A “run” is defined as a single stack sampling episode to determine the amount of dioxin-like compounds present in the gases leaving the stack. These data can be found in a database maintained by EPA’s Office of Solid Waste as documented in: Final Technical Support Document for Hazardous Waste Combustors (HWC) MACT Standards; HWC Emissions Database, Volume II; Appendix A: Cement Kilns: In: Final Standards for Hazardous Air Pollutants For Hazardous Waste Combustors; Final Rule; September 30, 1999 (64 FR 52828). This cement kiln dioxin/furan database may be accessed on the Internet at the following URL: <https://www.epa.gov/stationary-sources-air-pollution/hazardous-waste-combustors-microsoft-access-database-supplemental>.

In order to estimate annual air emissions of dioxin-like compounds using the EPA default emissions factors, the owner/operator are advised to follow the calculation steps given in Section 3.1. Please note that the EPA default emissions factors are generally applicable to all Portland cement kilns burning hazardous waste regardless of primary fuel type; constituents of hazardous waste burned as supplemental fuel; air pollution control equipment installed at the kiln; temperature of the kiln and whether or not the kiln is a wet or dry process. However, the emissions of dioxin-like compounds in Table 4-11 are more representative of cement kilns that operate the air pollution control equipment at temperatures of 204°C (400°F) or less. Such temperatures are known to suppress the post combustion formation of dioxins and furans and result in lower emissions of dioxin-like compounds than if the temperatures were more elevated.

4.5.4 Hazardous Waste Incineration (HWI) Facilities

The four principal furnace designs employed for the combustion of hazardous waste in the United States are: liquid injection, rotary kiln, fixed hearth, and fluidized-bed incinerators (Dempsey and Oppelt, 1993). The majority of commercial operations are of the rotary kiln incinerator type. On-site (noncommercial) HWI technologies are an equal mix of rotary kiln and liquid injection facilities, with a few additional fixed hearths and fluidized bed operations (U.S. EPA, 1996h). Each of these HWI technologies is discussed below:

Rotary Kiln HWI: Rotary kiln incinerators consist of a rotating kiln, coupled with a high temperature afterburner. Because these are excess air units designed to combust hazardous waste in any physical form (i.e., liquid, semi-solid, or solid), rotary kilns are the most common type of hazardous waste incinerator used by commercial “off-site” operators. The rotary kiln is a horizontal cylinder lined with refractory material. Rotation of the cylinder on a slight slope provides for gravitational transport of the hazardous waste through the kiln (Buonicore, 1992a). The tumbling action of the rotating kiln causes mixing and exposure of the waste to the heat of combustion, thereby enhancing burnout. Solid and semi-solid wastes are loaded into the top of the kiln by an auger or rotating screw. Fluid and pumpable sludges and wastes are typically introduced into the kiln through a water-cooled tube. Liquid hazardous waste is fed directly into the kiln through a burner nozzle. Auxiliary fuel (natural gas or oil) is burned in the kiln chamber at start-up to reach elevated temperatures. The typical heating value of hazardous waste (i.e., 8,000 Btu/kg) is sufficient to sustain combustion without auxiliary fuel (U.S. EPA, 1996h). The combustion gases emanating from the kiln are passed through a high temperature afterburner chamber to more completely destroy organic pollutants entrained in the flue gases. Rotary kilns can be designed to operate at temperatures as high as 2,580°C, but more commonly operate at about 1,100°C.

Liquid Injection HWI: Liquid injection incinerators (LIIs) are designed to burn liquid hazardous waste. These wastes must be sufficiently fluid to pass through an atomizer for injection as droplets into the

combustion chamber. The LIIs consist of a refractory-lined steel cylinder mounted either in a horizontal or vertical alignment. The combustion chamber is equipped with one or more waste burners. Because of the rather large surface area of the atomized droplets of liquid hazardous waste, the droplets quickly vaporize. The moisture evaporates, leaving a highly combustible mix of waste fumes and combustion air (U.S. EPA, 1996h). Secondary air is added to the combustion chamber to complete the oxidation of the fume/air mixture.

Fixed Hearth HWI: Fixed hearths, the third principal hazardous waste incineration technology, are starved air or pyrolytic incinerators, which are two-stage combustion units. Waste is ram-fed into the primary chamber and incinerated below stoichiometric requirements (i.e., at about 50 to 80 percent of stoichiometric air requirements). The resulting smoke and pyrolytic combustion products are then passed through a secondary combustion chamber where relatively high temperatures are maintained by the combustion of auxiliary fuel. Oxygen is introduced into the secondary chamber to promote complete thermal oxidation of the organic molecules entrained in the gases.

Fluidized-bed HWI: The fourth hazardous waste incineration technology is the fluidized-bed incinerator, which is similar in design to that used in municipal solid waste incineration. In this configuration, a layer of sand is placed on the bottom of the combustion chamber. The bed is preheated by underfire auxiliary fuel at startup. During combustion of auxiliary fuel at start-up, the hot gases are channeled through the sand at relatively high velocity, and the turbulent mixing of combustion gases and combustion air causes the sand to become suspended (Buonicore, 1992a). This takes on the appearance of a fluid medium, hence the incinerator is termed a ‘fluidized-bed’ combustor. The incinerator is operated below the melting point temperature of the bed material. Typical temperatures of the fluid medium are within the range of 650 – 940°C. A constraint on the types of waste burned is that the solid waste particles must be capable of being suspended within the furnace. When the liquid or solid waste is combusted in the fluid medium, the exothermic reaction causes heat to be released into the upper portion of the combustion chamber. The upper portion is typically much larger in volume than the lower portion, and temperatures can reach 1,000°C (Buonicore, 1992a). This high temperature is sufficient to combust volatilized pollutants emanating from the combustion bed.

Most HWIs use APCDs to remove undesirable components from the flue gases that evolved during the combustion of the hazardous waste. These unwanted pollutants include suspended ash particles (particulate matter or PM), acid gases, metal, and organic pollutants. The APCD controls or collects these pollutants and reduces their discharge from the incinerator stack to the atmosphere. Levels and kinds of these combustion byproducts are highly site-specific, depending on factors such as waste composition and incinerator system design and operating parameters (e.g., temperature and exhaust gas velocity). The APCD is typically comprised of a series of different devices that work together to clean the exhaust combustion flue gas. Unit operations usually include exhaust gas cooling, followed by particulate matter and acid gas control.

Exhaust gas cooling may be achieved using a waste heat boiler or heat exchanger, mixing with cool ambient air, or injection of a water spray into the exhaust gas. A variety of different types of APCDs are employed for the removal of particulate matter and acid gases. Such devices include: wet scrubbers (such as venturi, packed bed, and ionizing systems), electrostatic precipitators, and fabric filters (sometimes used in combination with dry acid gas scrubbing). In general, the control systems can be grouped into the following three categories: wet, dry, and hybrid wet/dry systems. The controls for acid gases (either dry or wet systems) cause temperatures to be reduced preceding the control device. This impedes the extent of formation of CDDs and CDFs in the post-combustion area of the typical HWI. It is not unusual for stack concentrations of CDD/CDFs at a particular HWI to be in the range of 1 – 100 ng CDD/CDF/dscm (Helble, 1993), which is low in comparison to other waste incineration systems. The range of total CDD/CDF flue gas concentrations measured in the stack emissions of HWIs during trial burns across the

class of HWI facilities, however, has spanned four orders of magnitude (ranging from 0.1 – 1,600 ng/dscm) (Helble, 1993). The APCD systems are described below:

- **Wet Systems:** A wet scrubber is used for both particulate and acid gas control. Typically, a venturi scrubber and packed-bed scrubber are used in a back-to-back arrangement. Ionizing wet scrubbers, wet electrostatic precipitators, and innovative venturi-type scrubbers may be used for more efficient particulate control. Wet scrubbers generate a wet effluent liquid wastestream (scrubber blowdown), are relatively inefficient at fine particulate control compared to dry control techniques, and have equipment corrosion concerns. However, wet scrubbers do provide efficient control of acid gases and have lower operating temperatures (compared with dry systems), which may help control the emissions of volatile metals and organic pollutants.
- **Dry Systems:** In dry systems, a fabric filter or electrostatic precipitator (ESP) is used for particulate control. A fabric filter or ESP is frequently used in combination with dry scrubbing for acid gas control. Dry scrubbing systems, in comparison with wet scrubbing systems, are inefficient in controlling acid gases.
- **Hybrid Systems:** In hybrid systems, a dry technique (ESP or fabric filter) is used for particulate control, followed by a wet technique (wet scrubber) for acid gas control. Hybrid systems have the advantages of both wet and dry systems (lower operating temperature for capture of volatile metals, efficient collection of fine particulate, efficient capture of acid gases), while avoiding many of the individual disadvantages. In some hybrid systems, known as “zero discharge systems,” the wet scrubber liquid is used in the dry scrubbing operation, thus minimizing the amount of liquid byproduct waste
- **Uncontrolled HWIs:** Facilities that do not use any air pollution control devices fall under a separate and unique category. These are primarily liquid waste injection facilities, which burn low ash and chlorine content wastes; therefore, they are low emitters of PM and acid gases.

For purposes of estimating emissions factors, this document considers subdividing the combustors in each source category into design classes judged to have similar potential for CDD/CDF emissions. As explained below, it was decided not to subdivide dedicated HWIs.

Combustion research has identified three mechanisms involved in the emission of CDD/CDFs from combustion systems: (1) CDD/CDFs can be introduced into the combustor with the feed and pass through the system not completely burned/destroyed; (2) CDD/CDFs can be formed by chemical reactions inside the combustion chamber; and (3) CDD/CDFs can be formed by chemical reactions outside the combustion chamber. The total CDD/CDF emissions are likely to be the net result of all three mechanisms; however, the relative importance of the mechanisms can vary among source categories. In the case of HWIs, the third mechanism (i.e., post-combustion formation) is likely to dominate, because HWIs are typically operated at high temperatures and long residence times, and most have sophisticated real-time monitoring and controls to manage the combustion process. Therefore, any CDD/CDFs present in the feed or formed during combustion are likely to be destroyed before exiting the combustion chamber. Consequently, for purposes of generating emissions factors, it was decided not to subdivide this class on the basis of furnace type.

Emissions resulting from the post-combustion formation in HWIs can be minimized through a variety of technologies:

- **Rapid Flue Gas Quenching:** The use of wet and dry scrubbing devices to remove acid gases usually results in the rapid reduction of flue gas temperatures at the inlet to the PM APCD. If temperature is reduced below 200°C, the low-temperature catalytic formation of CDD/CDFs is substantially retarded.
- **Use of Particulate Matter (PM) Air Pollution Control Devices:** PM control devices can effectively capture condensed and adsorbed CDD/CDFs that are associated with the entrained

particulate matter (in particular, that which is adsorbed on unburned carbon containing particulates).

- **Use of Activated Carbon:** Activated carbon injection is used at some HWIs to collect (sorb) CDD/CDFs from the flue gas. This may be achieved using carbon beds or by injecting carbon and collecting it in a downstream PM APCD.

All of these approaches appear very effective in controlling dioxin emissions at dedicated HWIs, and insufficient emissions data are available to generalize about any minor differences. Consequently, for purposes of generating emissions factors, it was decided not to subdivide this class on the basis of APCD type.

In 1999, EPA promulgated final standards for the stack emission limits of dioxin and dioxin-like compounds from hazardous waste combustion facilities (64 FR 52828 - 53077; Final Standards for Hazardous Air Pollutants For Hazardous Waste Combustors; Final Rule; September 30, 1999). Table 4-12 displays mean CDD/CDF emissions factors for estimating air releases of dioxin and dioxin-like compounds from 12 hazardous waste combustion facilities tested in 2000 (U.S. EPA, 2002). The emissions factors in Table 4-12 were derived from facilities that were stack tested in 2000 and may not reflect current regulatory requirements. The promulgated regulations require periodic stack sampling for dioxin-like compounds for all commercial hazardous waste combustion facilities. The owner/operator of such facilities is encouraged to use actual facility-specific emissions data (i.e., Approach 1) in lieu of EPA's default emissions factors. Such data are the most representative and best data to use in estimating annual releases of dioxin-like compounds.

Table 4-12: Average Emissions Factors (ng/kg waste feed) for Estimating Air Releases of Dioxin and Dioxin-like Compounds from Hazardous Waste Combustion Facilities

CDD Congener	Emissions Factor (ng/kg waste feed)	CDF Congener	Emissions Factor (ng/kg waste feed)
2,3,7,8-TCDD	0.036	2,3,7,8-TCDF	0.6399
1,2,3,7,8-PeCDD	0.0907	1,2,3,7,8-PeCDF	0.8375
1,2,3,4,7,8-HxCDD	0.1395	2,3,4,7,8-PeCDF	0.735
1,2,3,6,7,8-HxCDD	0.4351	1,2,3,4,7,8-HxCDF	4.045
1,2,3,7,8,9-HxCDD	0.2178	1,2,3,6,7,8-HxCDF	3.001
1,2,3,4,6,7,8-HpCDD	2.699	1,2,3,7,8,9-HxCDF	2.637
1,2,3,4,6,7,8,9-OCDD	5.17	2,3,4,6,7,8-HxCDF	1.121
		1,2,3,4,6,7,8-HpCDF	28.71
		1,2,3,4,7,8,9-HpCDF	5.021
		1,2,3,4,6,7,8,9-OCDF	36.23
∑ CDD	8.79	∑ CDF	82.98
∑ Dioxin and dioxin-like compounds*		91.77	

Source: U.S. EPA (2002)

*∑ Dioxin and dioxin-like compounds = ∑ CDD + ∑ CDF

Assumes non-detect set to zero.

The updated regulations also state Existing HWIs equipped with waste heat boilers and dry scrubbers (as APCDs) cannot emit more than 0.28 ng I-TEQ/dscm. All other existing HWIs are limited to 0.4 ng I-TEQ/dscm of stack gas. Regulatory requirements are more strict for newly built HWIs: those equipped with waste heat boilers and dry scrubbers (as APCDs) cannot emit more than 0.11 ng I-TEQ/dscm, and all others are limited to 0.2 ng I-TEQ/dscm of stack gas (EPA, 2000). These emissions factors may also be

different values than previous versions of this guidance document included, reflecting the updated testing data.

SECTION 5.0 GLOSSARY

Abatement	Reducing the degree or intensity of, or eliminating, pollution.
Air Emission	The release or discharge of a pollutant by an owner or operator into the ambient air either by means of a stack or as a fugitive dust, mist, or vapor as a result inherent to the manufacturing, forming or combustion process.
Air Pollutant	Dust, fumes, smoke, and other particulate matter, vapor, gas, odorous substances, or any combination thereof. Also any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive substance or matter which is emitted into or otherwise enters the ambient air.
Air Pollution Control Device	Mechanism or equipment that cleans emissions generated by a source (e.g., an incinerator, industrial smokestack, or an automobile exhaust system) by removing pollutants that would otherwise be released to the atmosphere.
Ambient Measurement	A measurement of the concentration of a substance or pollutant within the immediate environs of an organism; taken to relate it to the amount of possible exposure.
Area Source	Any source of air pollution that is released over a relatively small area but which cannot be classified as a point source. Such sources may include vehicles and other small engines, small businesses and household activities, or biogenic sources such as a forest that releases hydrocarbons
BACT-Best Available Control Technology	An emission limitation based on the maximum degree of emission reduction (considering energy, environmental, and economic impacts) achievable through application of production processes and available methods, systems, and techniques. BACT does not permit emissions in excess of those allowed under any applicable Clean Air Act provisions. Use of the BACT concept is allowable on a case by case basis for major new or modified emissions sources in attainment areas and applies to each regulated pollutant.
Boiler	A vessel designed to transfer heat produced by combustion or electric resistance to water. Boilers may provide hot water or steam.
British Thermal Unit (Btu)	Unit of heat energy equal to the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit at sea level.
CAS Registration Number	A number assigned by the Chemical Abstract Service to identify a chemical.

Combustion	<p>1. Burning, or rapid oxidation, accompanied by release of energy in the form of heat and light.</p> <p>2. Refers to controlled burning of waste, in which heat chemically alters organic compounds, converting into stable inorganics such as carbon dioxide and water.</p>
Concentration	The relative amount of a substance mixed with another substance. An example is five ppm of carbon monoxide in air or 1 mg/l of iron in water.
Congener	A discrete chemical compound within a group of compounds having the same molecular weight and chemical/physical properties.
Cubic Feet Per Minute (CFM)	A measure of the volume of a substance flowing through air within a unit period of time.
Dioxin and Dioxin-like compounds	CDDs and CDFs substituted with chlorine substitution in the 2,3,7, and 8-positions along the molecule. There are 7 CDDs and 10 CDFs (for a total of 17 compounds) that meet this definition.
Discharge	The release of any waste stream or any constituent thereof, into the environment.
Design Capacity	The average daily flow that a treatment plant or other facility is designed to accommodate.
Detection Limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
Destruction and Removal Efficiency (DRE)	A percentage that represents the number of molecules of a compound removed or destroyed in an incinerator relative to the number of molecules entering the system (e.g., a DRE of 99.99 percent means that 9,999 molecules are destroyed for every 10,000 that enter; 99.99 percent is known as "four nines." For some pollutants, the RCRA removal requirement may be as stringent as "six nines.")
Effluent Guidelines	Technical EPA documents which set effluent limitations for given industries and pollutants.
Effluent	Wastewater--treated or untreated--that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.
Emissions Factor	The relationship between the amount of pollution produced and released into the environment and the amount of raw material processed, fuel consumed, or waste processed. For example, an emissions factor for a blast furnace making iron would be the number of grams of dioxin-like compounds per ton of raw materials.

Emission Inventory	A listing, by source, of the amount of contaminant released into the environment per year.
Emission	Pollution discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts.
Emission Standard	The maximum amount of air polluting discharge legally allowed from a single source, mobile or stationary.
End-of-the-pipe	Technologies such as scrubbers on smokestacks and catalytic converters on automobile tailpipes that reduce emissions of pollutants after they have formed.
Electrostatic precipitator	An air pollution control device that imparts an electric charge to particles in a gas stream causing them to collect on an electrode.
Emission Rate	The amount of a pollutant or contaminant emitted per unit of time.
Equivalent Method	Any method of sampling and analyzing for the presence and occurrence of a contaminant in an environmental sample which has been demonstrated to the EPA Administrator's satisfaction to be, under specific conditions, an acceptable alternative to normally used reference methods.
Fabric Filter	Large fabric bag, usually made of glass fibers, used to eliminate intermediate and large (greater than 20 PM in diameter) particles. This device operates like the bag of an electric vacuum cleaner, passing the air and smaller particles while entrapping the larger ones.
Flow Rate	The rate, expressed in gallons -or liters-per-hour, at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.
Flue Gas	The products of combustion, including pollutants, emitted to the air after a production process or combustion takes place
Fossil Fuel	Fuel derived from ancient organic remains; e.g., peat, coal, crude oil, and natural gas.
Fugitive Emissions	Emissions not caught by a capture system.
Gas Chromatography/Mass Spectrometer	Instrument that identifies the molecular composition and concentrations of various chemicals in water and soil samples.
Grab Sample	A single sample collected at a particular time and place that represents the composition of the water, air, or soil only at that time and place.

Hazardous Waste	Wastes that possess at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity), or appears on special EPA lists, as defined by RCRA Subtitle C.
Incineration	An engineered process using controlled flame combustion to thermally degrade waste materials.
Industrial Process Waste	Residues produced during manufacturing operations.
Industrial Sludge	Semi-liquid residue or slurry remaining from treatment of industrial water and wastewater.
Industrial Waste	Unwanted materials from an industrial operation; may be liquid, sludge, solid, or hazardous waste.
Land Application	Discharge of wastewater, sludge or solid waste onto the surface of the ground for treatment or reuse.
Maximum Available Control Technology (MACT)	The emission standard for sources of air pollution requiring the maximum reduction of hazardous emissions, taking cost and feasibility into account. Under the Clean Air Act Amendments of 1990, the MACT must not be less than the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources.
Maximum Contaminant Level	The maximum permissible level of a contaminant in water delivered to any user of a public system. MCLs are enforceable standards.
Media	Specific environments--air, water, soil--which are the subject of regulatory concern and activities.
Method Detection Limit (MDL)	See limit of detection.
Million-Gallons Per Day (MGD)	A measure of water flow.
Molecule	The smallest division of a compound that still retains or exhibits all the properties of the substance.
Monitoring	The direct measurement of the amount or concentration of a contaminant in an environmental medium.
National Emissions Standards for Hazardous Air Pollutants (NESHAPS)	Emissions standards set by EPA for an air pollutant not covered by NAAQS that may cause an increase in fatalities or in serious, irreversible, or incapacitating illness. Primary standards are designed to protect human health, secondary standards to protect public welfare (e.g., building facades, visibility, crops, and domestic animals).
National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean Water Act which prohibits discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a tribal government on an Indian reservation.

Outfall	The place where effluent is discharged into receiving waters.
Particulates	<ol style="list-style-type: none"> 1. Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. 2. Very small solids suspended in water; they can vary in size, shape, density and electrical charge and can be gathered together by coagulation and flocculation.
Performance Standards	<ol style="list-style-type: none"> 1. Regulatory requirements limiting the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in emissions from incinerators. 2. Operating standards established by EPA for various permitted pollution control systems, asbestos inspections, and various program operations and maintenance requirements.
Physical and Chemical Treatment	Processes generally used in large-scale wastewater treatment facilities. Physical processes may include air-stripping or filtration. Chemical treatment includes coagulation, chlorination, or ozonation. The term can also refer to treatment of toxic materials in surface and ground waters, oil spills, and some methods of dealing with hazardous materials on or in the ground.
Quality Assurance/Quality Control	A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.
Receiving Waters	A river, lake, ocean, stream or other watercourse into which wastewater or treated effluent is discharged.
Representative Sample	A portion of material, medium or water that is as nearly identical in content and consistency as possible to that in the larger body of material, medium or water being sampled.
Sampling Frequency	The interval between the collection of successive samples.
Scrap	Materials discarded from manufacturing operations that may be suitable for reprocessing.
Scrubber	An air pollution device that uses a spray of water or reactant or a dry process to trap pollutants in emissions.
Site	An area or place within the jurisdiction of the EPA and/or a state.
Sludge	Any solid, semisolid or liquid waste generated from a municipal, commercial, or industrial wastewater treatment plant, water supply treatment plant, or air pollution control facility, or any other such waste having similar characteristics.

Smelter	A facility that melts or fuses ore, often with an accompanying chemical change, to separate its metal content. Emissions cause pollution. "Smelting" is the process involved.
Source	Any building, structure, facility or installation from which there is or may be the discharge of pollutants into the environment.
Source Characterization	Measurements made to estimate the rate of release of pollutants into the environment from a source such as an incinerator, landfill, etc.
Solid Waste	Non-liquid, non-soluble materials ranging from municipal garbage to industrial wastes that contain complex and sometimes hazardous substances. Solid wastes also include sewage sludge, agricultural refuse, demolition wastes, and mining residues. Technically, solid waste also refers to liquids and gases in containers.
Stack	Any chimney, flue, vent, roof monitor, conduit or duct arranged to discharge emissions to the air.
Standards	Norms that impose limits on the amount of pollutants or emissions produced. EPA establishes minimum standards, but states are allowed to be stricter.
Surface Water	All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.)
Technology-Based Limitations	Industry-specific effluent limitations based on best available preventive technology applied to a discharge when it will not cause a violation of water quality standards at low stream flows. Usually applied to discharges into large rivers.
Technology-Based Standards	Industry-specific effluent limitations applicable to direct and indirect sources which are developed on a category-by-category basis using statutory factors, not including water-quality effects.
Treatment Plant	A structure built to treat wastewater before discharging it into the environment. Treatment, Storage, and Disposal Facility: Site where a hazardous substance is treated, stored, or disposed of. TSD facilities are regulated by EPA and states under RCRA.
Trial Burn	An incinerator test in which emissions are monitored for the presence of specific organic compounds, particulates, and hydrogen chloride. Trichloroethylene (TCE): A stable, low boiling-point colorless liquid, toxic if inhaled. Used as a solvent or metal degreasing agent, and in other industrial applications.

Utility Boiler	Coal, oil or natural gas fired boiler used to exchange heat of combustion to steam to operate an electric generator for the expressed purpose of producing electricity. Alternative term is Power Plant.
Venturi Scrubbers	Air pollution control devices that use water to remove particulate matter from emissions
Waste Feed	The continuous or intermittent flow of wastes into an incinerator.
Waste Generation	The weight or volume of materials and products that enter the waste stream before recycling, composting, landfilling, or combustion takes place. Also can represent the amount of waste generated by a given source or category of sources.
Waste Stream	The total flow of solid waste from homes, businesses, institutions, and manufacturing plants that is recycled, burned, or disposed of in landfills, or segments thereof such as the "residential waste stream" or the "recyclable waste stream."
Waste Treatment Plant	A facility containing a series of tanks, screens, filters and other processes by which pollutants are removed.
Waste Treatment Stream	The continuous movement of waste from generator to treater and disposer.
Wastewater	The spent or used water from a home, community, farm, or industry that contains dissolved or suspended matter. Water Pollution: The presence in water of enough harmful or objectionable material to damage the water's quality.
Water Quality Criteria	Levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.
Water Quality Standards	State-adopted and EPA-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.
Water Quality-Based Limitations	Effluent limitations applied to dischargers when mere technology-based limitations would cause violations of water quality standards. Usually applied to discharges into small streams.
Water Quality-Based Permit	A permit with an effluent limit more stringent than one based on technology performance. Such limits may be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry or water supply).

SECTION 6.0 CONVERSION FACTORS

Abbreviation	From	Multiply by	To	Abbreviation
Weight (English to Metric)				
oz	ounces	28.35	grams	g
oz	ounces	0.028	kilogram	kg
lb	pounds	453.59	grams	g
lb	pounds	0.454	kilograms	kg
t	tons, short	0.907	metric tons	mt
t	tons, short	907	kilograms	kg
t	tons, long	1.016	metric tons	mt
Weight (Metric to English)				
g	grams	0.002	pounds	lb
g	grams	15.43	grains	gr
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
kg	kilograms	0.0011	tons, short	t
kg	kilograms	0.001	tons, long	t
mt	metric tons	0.984	tons, long	t
mt	metric tons	1.102	tons, short	t
mt	metric tons	2,204.6	pounds	lb

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