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# **The Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the United States: The Year 2000 Update**

## NOTICE

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## ABSTRACT

The purpose of this report is to present a comprehensive inventory and overview of sources and environmental releases of dioxin-like compounds in the United States. The major identified sources of environmental releases of dioxin-like compounds are grouped into six broad categories: combustion sources, metals smelting, refining and process sources, chemical manufacturing sources, biological and photochemical processes sources, and environmental reservoirs. Estimates of annual releases to land, air, and water are presented for each source category and summarized for reference years 1987, 1995, and 2000. The quantitative results are expressed in terms of the toxicity equivalent (TEQ) of the mixture of polychlorinated dibenzo-*p*-dioxin (CDD) and polychlorinated dibenzofuran (CDF) compounds present in environmental releases using a procedure sanctioned by the World Health Organization (WHO) in 1998. This TEQ procedure translates the complex mixture of CDDs and CDFs characteristic of environmental releases into an equivalent toxicity concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), the most toxic member of this class of compounds. Using this WHO procedure, the annual releases of TEQ<sub>DF</sub>-WHO<sub>98</sub> to the U.S. environment over the three reference years are 13,962 g in 1987, 3,280 g in 1995, and 1,529 g in 2000. This analysis indicates that between reference years 1987 and 2000, there was approximately 89% reduction in the releases of dioxin-like compounds to the circulating environment of the United States from all known sources combined. In 1987 and 1995, the leading source of dioxin emissions to the U.S. environment was municipal waste combustion; however, because of reductions in dioxin emissions from municipal waste combustors, it dropped to the third ranked source in 2000. Burning of domestic refuse in backyard burn barrels remained fairly constant over the years, but in 2000, it emerged as the largest source of dioxin emissions.

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## LIST OF ABBREVIATIONS AND ACRONYMS

AHA	American Hospital Association
AMSA	Association of Metropolitan Sewerage Agencies
APCD	Air pollution control device
BDDs	Polybrominated dibenzo- <i>p</i> -dioxins
BDFs	Polybrominated dibenzofurans
Btu	British thermal unit
CaCl <sub>2</sub>	Calcium chloride
CARB	California Air Resources Board
CBI	Confidential business information
CDD	Polychlorinated dibenzo- <i>p</i> -dioxin
CDF	Polychlorinated dibenzofuran
CFR	Code of Federal Regulations
CSF	Confidential Statement of Formula
CKD	Cement Kiln Dust
CO	Carbon Monoxide
CO <sub>2</sub>	Carbon Dioxide
CuCl	Copper (I) chloride
CuCl <sub>2</sub>	Copper (II) chloride
D	Symbol for Congener Class: Dibenzo- <i>p</i> -dioxin
D	Symbol for di (i.e., Two Halogen Substitution)
DBF	Dibenzofuran
DCBz	Dichlorobenzene
DCI	Data Call-In
DCP	Dichlorophenol
DL	Detection limit
dscm	Dry standard cubic meter
DSI	Dry sorbent injection
EDC	Ethylene dichloride
EIA	Energy Information Administration

## LIST OF ABBREVIATIONS AND ACRONYMS (continued)

EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitator
FF	Fabric filter
FCEM	Field Chemical Emissions Measurement
FeCl <sub>3</sub>	Ferric (iron) chloride
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GAC	Granular activated carbon
GC/ECD	Gas chromatography/electron capture detector
GC/MS	Gas chromatography/mass spectrometry
HCl	Hydrogen chloride
HCBz	Hexachlorobenzene
HDD	Halogenated dibenzo- <i>p</i> -dioxin
HDF	Halogenated dibenzofuran
HWI	Hazardous waste incinerator
HxCB	Hexachlorobiphenyl
IUPAC	International Union of Pure and Applied Chemistry
KCl	Potassium chloride
LOQ	Limit of quantitation
MB-WW	Mass burn waterwall
MCBz	Monochlorobenzene
MgCl <sub>2</sub>	Magnesium chloride
MgO	Magnesium oxide
MSW	Municipal solid waste
MWI	Medical waste incinerator
NaCl	Sodium chloride
NaOCl	Sodium hypochlorite
NCASI	National Council of the Paper Industry for Air and Stream Improvement
NiCl <sub>2</sub>	Nickel chloride
NiO	Nickel oxide

## LIST OF ABBREVIATIONS AND ACRONYMS (continued)

Nm <sup>3</sup>	Standard cubic meter
NMOC	Nonmethane organic compound
OAQPS	Office of Air Quality Planning and Standards
O <sub>2</sub>	Molecular oxygen
OH	Hydroxide ion
OPP	Office of Pesticide Programs
ORD	Office of Research and Development
OSW	Office of Solid Waste
Pb	Lead
PCA	Portland Cement Association
PCB	Polychlorinated biphenyl
PCP	Pentachlorophenol
PCP-Na	Pentachlorophenate
PeCB	Pentachlorobiphenyl
PeCBz	Pentachlorobenzene
PM	Particulate matter
POTW	Publicly owned treatment works
ppb	Parts Per Billion
ppm	Parts Per Million
ppmv	Parts per million (volume basis)
ppt	Parts per trillion
PVC	Polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RDF	Refuse-derived fuel
SIC	Standard Industrial Classification
SNUR	Significant New Use Rule
SO <sub>2</sub>	Sulfur dioxide
TCBz	Trichlorobenzene
TCDD	2,3,7,8-tetrachlorobideno- <i>p</i> -dioxin

## LIST OF ABBREVIATIONS AND ACRONYMS (continued)

TCDF	2,3,7,8-tetrachlorobenzofuran
TeCB	Tetrachlorobiphenyl
TeCP	Tetrachlorophenol
TEF	Toxicity equivalency factor
TEQ	Toxicity equivalent
TEQ/yr	Toxicity equivalents per year
TiCl <sub>4</sub>	Titanium tetrachloride
TrCB	Trichlorobiphenyl
TrCP	Trichlorophenol
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4-DB	4-(2,4-Dichlorophenoxy) butyric acid
2,4-DCP	2,4-Dichlorophenol
2,4-DP	2-(2,4-Dichlorophenoxy) propionic acid
2,4,5-T	2,4,5-Trichlorophenoxy (phenoxy herbicides)
U.K.	United Kingdom
USDA	U.S. Department of Agriculture
VCM	Vinyl chloride monomer
WHO	World Health Organization
WS	Wet scrubber

## FOREWORD

The purpose of this report is to present an inventory of sources and environmental releases of dioxin-like compounds in the United States. This inventory is associated with three distinct reference years: 1987, 1995, and 2000. The presentation of information in this manner permits the ranking of sources by magnitude of annual release and allows for the evaluation of environmental trends over time.

The term “dioxin-like” includes congeners of polychlorinated dibenzo-*p*-dioxins (CDDs), polychlorinated dibenzofurans (CDFs) having chlorine atoms in the 2,3,7,8 positions on the molecule, and certain coplanar-substituted polychlorinated biphenyls (PCBs). Dioxin-like refers to the fact that these compounds have similar chemical structure and physical-chemical properties and invoke a common battery of toxic response. Because of their hydrophobic nature and resistance towards metabolism, these chemicals persist and bioaccumulate in fatty tissues of animals and humans. Consequently, the principal route of chronic population exposure is through the dietary consumption of animal fats, fish, shellfish, and dairy products. Dioxin-like compounds are persistent in soils and sediments, with environmental half-lives ranging from years to several decades. Understanding the sources and environmental releases of dioxin-like compounds is fundamental to ultimately linking sources with population exposures. It is through such understanding that actions can be taken to reduce human exposures.

This current inventory is an update of an external review draft report entitled, *The Inventory of Sources of Dioxin in the United States* (EPA/600/P-98/002Aa), dated April 1998. The 1998 draft inventory presented annual estimates of environmental releases for reference years 1987 and 1995. A meeting of scientific and engineering experts was convened June 3-4, 1998, to review the scientific soundness of EPA’s dioxin inventory. Overall, the reviewers found the inventory report to be comprehensive and well documented and the “emission factor approach” that was used to develop the inventory to be scientifically defensible. The review committee recommended that EPA (a) take a less conservative approach for including data on emissions of dioxin-like compounds from sources, especially data from foreign countries and those found in the nonpeer-reviewed literature; (b) adopt a qualitative ranking system that clearly indicates the relative amount of uncertainty behind the calculations of annual releases of dioxin-like compounds; (c) present the inventory of sources and environmental releases specific

to the reference years, because technologies and emissions of dioxin from sources changes over time; and (d) present the dioxin inventory as a summary table of sources and estimated annual releases, including quantifiable as well as poorly understood sources. The current inventory reflects comments made by the review committee and also represents an update with the inclusion of a third reference year, 2000.

This updated inventory of sources and environmental releases of dioxin-like compounds concludes that, between 1987 and 2000, there was an approximately 89% reduction in the release of dioxin-like compounds to the circulating environment of the United States from all known sources combined. Annual emission estimates ( $TEQ_{DF-WHO_{98}}$ ) of releases of CDDs/CDFs to air, water, and land from reasonably quantifiable sources are approximately 1,529 g in reference year 2000; 3,280 g in reference year 1995; and 13,962 g in reference year 1987. In 1987 and 1995, the leading sources of dioxin emissions to the U.S. environment were municipal waste combustors. The inventory also identifies bleached chlorine pulp and paper mills as a significant source of dioxin to the aquatic environment in 1987 but a minor source in 1995 and 2000. The inventory concludes that the major source of dioxin in 2000 was the uncontrolled burning of refuse in backyard burn barrels in rural areas of the United States.

The reduction in environmental releases of dioxin-like compounds from 1987 to 2000 is attributable to source-specific regulations, improvements in source technology, advancements in the pollution control technologies specific to controlling dioxin discharges and releases, and the voluntary actions of U.S. industries to reduce or prevent dioxin releases.

Peter W. Preuss, Ph.D.  
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## **PREFACE**

This external review draft report presents an inventory of all known sources and environmental releases of dioxin-like compounds in the United States associated with reference years 1987, 1995, and 2000. This perspective allows for the observation of time trends of releases of dioxin-like compounds to the open and circulating environment from industrial, combustion, chemical, and ferrous and nonferrous metal smelting processes as they are configured and operated in the United States. The assessment was prepared by the National Center for Environmental Assessment, which is the health risk assessment program in the Office of Research and Development.

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## EXECUTIVE SUMMARY

### Background

*The Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the United States: The Year 2000 Update* presents estimates of annual releases of dioxin-like compounds specific to three reference years: 1987, 1995, and 2000. It is a detailed review and description of all known sources and their associated activities that cause these compounds to be released into the circulating environment, that is, to air, water, and land.

The primary purposes of the report are to:

1. Document and describe sources in the United States which release dioxin-like compounds into the circulating environment.
2. Quantify annual releases to the environment of the United States from known sources in a scientific and transparent manner.
3. Provide a reliable basis for time-trends analyses.

This is the second dioxin source inventory issued by the U.S. Environmental Protection Agency (EPA). The first one was issued in draft form and covered the years 1987 and 1995 (U.S. EPA, 1998a). The current effort updates the earlier document and adds annual release estimates for the year 2000. The Agency anticipates continuing to issue updates in future years.

### Approach

Only sources judged to have a reasonable likelihood for releases to the “open and circulating environment” were addressed in this document. The document discusses both contemporary formation sources and reservoir sources. Reservoirs are materials or places that contain previously formed CDDs/CDFs or dioxin-like PCBs that have the potential for redistribution and circulation in the environment. Potential reservoirs include soils, sediments, biota, water, and some anthropogenic materials. Reservoirs become sources when they release compounds to the circulating environment. While reservoir sources are discussed in the

document, they are not counted as part of the national inventory because they are not original releases.

The emissions were computed on the basis of an emission factor and activity level. The emission factor is the amount of dioxin emitted per unit of activity and is determined via sampling and analyzing the environmental releases from the source. The activity level reflects how much action is associated with a release and can take several forms such as kilograms of material processed per year by an industrial facility, vehicle miles traveled per year by trucks and automobiles, and liters of wastewater discharged into surface water from industrial sources. These factors are multiplied to arrive at an estimate of total environmental releases for a given year. The confidence in the accuracy of both the emission factor and activity level are rated as low, medium, or high based on the quality and representativeness of the data. The overall estimate of environmental release is also rated as low, medium, or high based on the lowest rating assigned to either the emission factor or activity level. In some cases, the data were not adequate to support even a low confidence rating. These cases were treated in two ways. If the data were sufficient to make an approximate, but clearly nonrepresentative estimate of releases, these were labeled as preliminary and not included in the national quantitative inventory. If the limited data suggested that dioxin releases were possible from a source, but were not adequate to support emission calculations, the source was labeled as unquantifiable. This approach resulted in the following classification scheme:

Category A	High Confidence	Included in the national quantitative inventory
Category B	Medium Confidence	
Category C	Low Confidence	
Category D	Preliminary	Not included in the national quantitative inventory
Category E	Unquantifiable	

Throughout this document, environmental release estimates are presented in terms of toxic equivalents (TEQs). TEQs are derived from a toxicity weighting system that converts all mixture components to a single value normalized to the toxicity of 2,3,7,8-TCDD (see Section 1.1.4 for details). This is done for convenience in presenting summary information and to

facilitate comparisons across sources. For many situations, however, it is important to use the individual CDD/CDF and PCB congener values rather than TEQs. The full congener-specific release rates for most sources are given in an electronic database that will become available as a companion to this document.

## **Results - Total Environmental Releases**

Tables 1-6 and 1-7 in Chapter 1 show the emission estimates for all sources that could be quantified, i.e., Categories A, B, C, and D. The Category D estimates are clearly labeled as outside the national inventory. Category E sources are shown in Table 1-5.

For the year 2000, EPA makes the following conclusions:

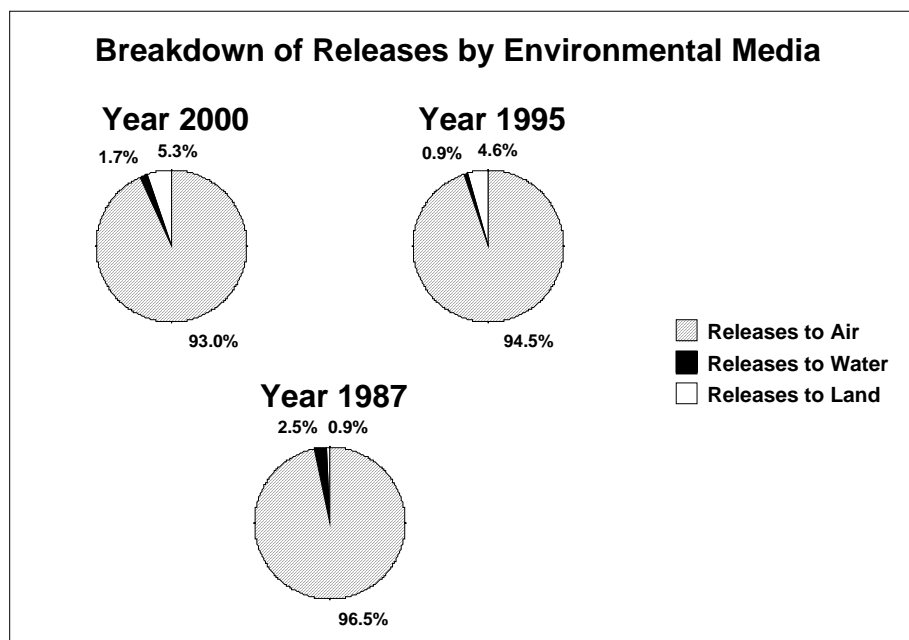
- The total releases in the inventory (Categories A, B, and C) were 1,529 g TEQ<sub>DF</sub>-WHO<sub>98</sub>/yr. Releases to the air accounted for 92% of the total releases. The top three sources were backyard barrel burning of refuse (32%), medical waste incinerators (MWIs) (24%), and municipal waste combustors (MWCs) (5%).
- The contemporary formation sources included Category D air releases totaling 6,777 g TEQ<sub>DF</sub>-WHO<sub>98</sub>/yr. Forest fires accounted for 72% of the total releases.
- A total of 18 contemporary formation sources were identified as Category E.
- Releases from only two reservoir sources could be estimated for 2000: urban runoff to surface water 142 g TEQ<sub>DF</sub>-WHO<sub>98</sub> and rural soil erosion to surface water 2,500 g TEQ<sub>DF</sub>-WHO<sub>98</sub>. Both of these estimates are preliminary (i.e., Category D). Releases from the other reservoirs (air, sediment, water, and biota) could not be quantified (i.e., Category E).

The following table summarizes the environmental releases of dioxin from all sources in the inventory for years 2000, 1995, and 1987. It shows the sources in ranked order from highest to lowest and also shows the percent contribution of each source to the total emissions. In 1987 and 1995, the leading source of dioxin emissions to the U.S. environment was municipal waste combustion; however, because of reductions in dioxin emissions from MWCs, it dropped to the third ranked source in 2000. Burning of domestic refuse in backyard burn barrels remained fairly constant over the years, but in 2000, it emerged as the largest source of dioxin emissions.

### Top ten dioxin emitting sources for the years 2000, 1995, and 1987

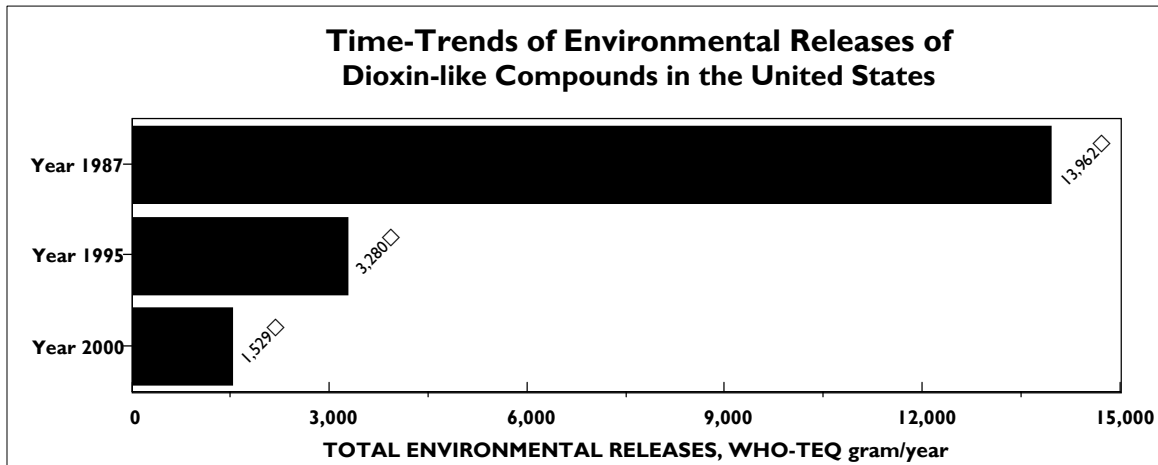
Ranking of the year 2000 sources	Year 2000 Grams	Percent of Total	Ranking of the year 1995 sources	Year 1995 Grams	Percent of Total	Ranking of the year 1987 sources	Year 1987 Grams	Percent of Total
Backyard barrel burning of refuse	498.53	32.59%	Municipal waste combustion	1,250.00	38.11%	Municipal waste combustion	8,877.00	63.58%
Medical waste/pathological incineration	378.00	24.71%	Backyard barrel burning of refuse	628.00	19.15%	Medical waste/pathological incineration	2,590.00	18.55%
Municipal waste combustion	78.90	5.16%	Medical waste/pathological incineration	488.00	14.88%	Secondary copper smelters	983.00	7.04%
Municipal wastewater treatment sludge	78.20	5.11%	Secondary copper smelters	271.00	8.26%	Backyard barrel burning of refuse	604.00	4.33%
Coal fired-utility boilers	69.50	4.54%	Cement kilns (hazardous waste burning)	156.10	4.76%	Bleached chemical wood pulp and paper mills	356.00	2.55%
Cement kilns (hazardous waste burning)	68.40	4.47%	Municipal wastewater treatment sludge	116.10	3.54%	Cement kilns (hazardous waste burning)	117.80	0.84%
Diesel heavy duty trucks	65.40	4.28%	Coal fired-utility boilers	60.10	1.83%	Municipal wastewater treatment sludge	76.60	0.55%
Primary Magnesium production	42.00	2.75%	Diesel heavy duty trucks	33.30	1.02%	Coal fired-utility boilers	50.80	0.36%
Industrial wood combustion	41.50	2.71%	Secondary aluminum smelters	29.10	0.89%	Automobiles using leaded gasoline	37.50	0.27%
Secondary aluminum smelting	35.90	2.35%	2,4-Dichlorophenoxy acetic acid	28.90	0.88%	2,4-Dichlorophenoxy acetic acid	33.40	0.24%
Other	173.16	11.32%	Other	219.33	6.69%	Other	236.29	1.69%
<i>Total Environmental Releases</i>	1529.49	100.00%	<i>Total Environmental Releases</i>	3,279.93	100.00%	<i>Total Environmental Releases</i>	13,962.39	100.00%

Environmental releases of CDDs/CDFs in the United States occur from a wide variety of sources but are dominated by releases to the air from combustion sources. The following pie charts summarize the breakdown of CDD/CDF releases to air, water, and land for each of the reference years.



### Results - Time Trends

A significant reduction in total CDD/CDF environmental releases has occurred since 1987. EPA's best estimates of releases of CDDs/CDFs to air, water, and land (from reasonably quantifiable sources) are approximately 1,529 g TEQ<sub>DF</sub>-WHO<sub>98</sub> in reference year 2000; 3,280 g TEQ<sub>DF</sub>-WHO<sub>98</sub> in reference year 1995; and 13,962 g TEQ<sub>DF</sub>-WHO<sub>98</sub> in reference year 1987 (see the following figure). From 1987 to 2000 there was approximately an 89% reduction in releases to all media. Most of the reduction in dioxin releases (77%) occurred in the time period from 1987 to 1995.



Reductions in environmental releases of dioxin-like compounds are attributed primarily to reductions in air emissions from MWCs, MWIs, and cement kilns burning hazardous waste and from wastewater discharged into surface waters from pulp and paper mills using chlorine. These reductions have occurred from a combination of regulatory activities, improved emission controls, voluntary actions on the part of industry, and the closing of a number of facilities. The following table shows the reductions made among the largest sources.

Source category	Media release	Reference year 2000 (g TEQ <sub>DF</sub> -WHO <sub>98</sub> )	Reference year 1987 (g TEQ <sub>DF</sub> -WHO <sub>98</sub> )	Percent reduction in environmental releases
Municipal waste combustion	Air	78.9	8877	>99
Medical waste incineration	Air	378	2590	85
Cement kilns burning hazardous waste	Air	68.4	117.8	42
Bleached chemical wood pulp and paper mills	Surface water	1	356	>99

## **Results - Sources Not Considered in the Inventory**

Significant amounts of the dioxin-like compounds produced annually in the United States are not considered releases to the open circulating environment and therefore, are not included in the national inventory. Examples include dioxin-like compounds generated internal to a process but destroyed before release, and waste streams that are disposed of in approved landfills.

A number of contemporary formation sources were classified as Category D or E sources and therefore, were not included in the inventory. The largest contemporary formation Category D sources are forest fires, and accidental fires at municipal solid waste landfills. Taken together, these sources have the potential to significantly increase the present inventory if preliminary release estimates are confirmed.