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Inventory of U.S. 2012 dioxin emissions to atmosphere

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ABSTRACT

In 2006, the U.S. EPA published an inventory of dioxin emissions for the U.S. covering the period from 1987–2000. This paper is an updated inventory of all U.S. dioxin emissions to the atmosphere in the year 2012. The sources of emissions of polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), collectively referred to in this paper as "dioxins", were separated into two classes: controlled industrial and open burning sources. Controlled source emissions decreased 95.5% from 14.0 kg TEQ in 1987 to 0.6 kg in 2012. Open burning source emissions increased 44% from 2.3 kg TEQ in 1987 to 3.3 kg in 2012. The 2012 dioxin emissions from 53 U.S. waste-to-energy (WTE) power plants were compiled on the basis of detailed data obtained from the two major U.S. WTE companies, representing 84% of the total MSW combusted (27.4 million metric tons). The dioxin emissions of all U.S. WTE plants in 2012 were 3.4 g TEQ and represented 0.54% of the controlled industrial dioxin emissions, and 0.09% of all dioxin emissions from controlled and open burning sources.

1. Introduction

After the 1970 Clean Air Act, the U.S. started regulating emissions from all industrial plants. Following the Clean Air Act Amendments of 1990, the U.S. Environmental Protection Agency (EPA) promulgated the Maximum Achievable Control Technology (MACT) regulations for air pollutants, including dioxins. The MACT standards resulted in large reductions in toxic air emissions across all industries, by over 90% for most pollutants (US EPA, 2000). In particular, these standards resulted in significant emission reductions from municipal waste combustors (MWCs), the regulatory definition that EPA applies to both early municipal solid waste (MSW) incinerators and modern waste-to-energy facilities (WTE).

The first U.S. waste incinerator plant was built in 1885, in New York City, and hundreds more were operating by the middle of the 20th century. Those early plants were quite different from today's modern municipal solid waste (MSW) thermal treatment facilities, which produce steam and electricity, recover metals, and are generally referred to as Waste-to-Energy (WTE) power plants. Most of the current WTE capacity in the U.S. was built between 1980–1996. In the late nineties, the new EPA MACT requirements resulted in the closing of nearly forty of the older incinerators and the retrofitting of the remaining WTE plants with emission controls needed to meet the new MACT standards. As of 2014, there were 84 waste-to-energy facilities in 23 states, processing 27.4 million metric tons annually and generating over 14.5 billion kilowatt hours of electricity, corresponding to 0.36% of the 4 TWh U.S. total (Michaels, 2014).

This study examined the current level of dioxin emissions to the atmosphere from various U.S. sources and the relative contribution of the WTE industry to the total dioxin emissions. The generic term "dioxins" refers to 17 structurally related halogenated tricyclic aromatic hydrocarbons, 53 polychlorinated dibenzo-p-dioxins, and 54 polychlorinated dibenzofurans. Dioxins are persistent organic pollutants, released into the environment from several sources. The health effects due to exposure to dioxins, in particular one of the most toxic dioxin compound – 2,3,7,8-Tetrachlorodibenzo-p-diox in (TCDD) – have been studied extensively (US EPA, 2012). Dioxin toxicity equivalency factors (TEFs), are used to compare the toxicities of 16 other toxic dioxins to that of 2,3,7,8 TCDD and thus provide a total Toxic Equivalent (TEQ) amount for all 17 dioxin compounds. The TEFs used in this study are those provided by the World Health Organization (WHO, 1998) and are known as the WHO I-TEF. The total TEQ thus provides a universal basis to assess dioxin emissions from various sources.

In 2006, the U.S. EPA published an inventory of dioxin emissions for the U.S. covering the period from 1987 to 2000 (US EPA, 2006). This paper is a 2012 inventory of all dioxin emissions in the U.S.

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2. Methodology used

Emissions from most sources were calculated using the protocol provided by the Environmental Protection Agency in their reports on dioxin emissions. The approach used is based on an emissions factor that relates the "*mass of [P]CDDs/[P]CDFs released into the environment with some measure of activity (e.g., kilograms of material processed per year, vehicle miles traveled per year, etc.). It is developed by averaging the emission factors for the tested facilities or activities within the particular classification of sources*" (US EPA, 2013). Emissions are calculated by multiplying this "average emissions factor" by the activity level for that source.

Unless specified, the emission factors used in this report are the same as those published in the EPA report (US EPA, 2006) while dioxin quantities emitted are expressed in toxic equivalent grams (grams TEQ), as described in the previous section. Emissions are separated into two source categories: For controlled industrial sources, accurate emissions tests and activity levels were used, while for open burning sources, best emissions tests and estimates were used; of course, emissions from this second category are more uncertain.

2.1. Sources of information

The controlled sources of dioxins are grouped into five classes:

- **Waste to energy**.
- **Waste incineration**.
- **Electricity and heat generation**: fuel combustion for electricity generation, heating, and vehicles.
- **Metallurgical processes**: metal smelting, refining, and processing.
- **Cement and asphalt production**.

Other sources are grouped into a sixth class:

- **Open burning processes**: refer to minimally or non controlled combustion including, backyard barrel burning, agricultural burning, construction debris, yard waste and fires (forest, vehicle, landfill, building).

For each emissions class, the EPA 2000 activity levels were first recalculated in order to test the validity of the calculations. Classes with annual emissions of less than 2 g TEQ, for 1995 and 2000 (US EPA, 2013), were not included in the inventory.

The following sections describe the calculations for emissions directly linked to the management of municipal solid waste: waste to energy plants, landfill gas combustion, and landfill fires. For more information on other dioxin sources mentioned in this paper, the reader is referred to the Columbia University thesis by Dwyer (2014).

2.2. WTE plants

Dioxin emissions from WTE plants were calculated using the results of the 2012 stack tests, as reported to state environmental agencies, of all facilities operated by the two major U.S. WTE companies, Covanta Energy and Wheelabrator Technologies. All together, these plants represent 84% of the U.S. WTE capacity (Van Brunt, 2014; Porter, 2014; Shin, 2014). The other U.S. plants belong to various municipalities and were assumed to have the same average emissions per short ton of waste processed.

The U.S. EPA standard, or MACT limit, for *total* dioxin concentration is 30 ng per dry standard cubic meter (dscm) corrected to 7% oxygen (O_2) [ref. to 40 CFR 60 Subpart Cb], for units constructed prior to 2006. WTE facilities are required annually to measure total dioxin concentrations in the stack gas exhaust to demonstrate compliance with the MACT limit.

For this study, measured stack exhaust dioxin concentrations were converted to annual mass emissions based on the EPA estimate of volume of combustion components per unit of heat content (*F*-Factor) of 0.257 dry standard cubic meters (dscm) at 0% O_2 per MJ [ref. to 40 CFR 60 Appendix A, Method 19, Table 19-2]

Table 1
2012 dioxin emissions of 57 U.S. WTE plants. *Sources:* Van Brunt (2014) and Porter (2014).

Facility #	Total dioxin concentration (ng/dscm)	TEQ dioxins (ng/dscm)	Annual dioxin emissions (g TEQ)	Ratio of total dioxins to TEQ dioxins
1	1.7	0.0153	0.0474	111.1
2	1.1	0.0197	0.0635	56.8
3	4.0	0.0322	0.0221	124.2
4	0.9	0.0114	0.0280	75.5
5	10.9	0.1133	0.0640	96.2
6	2.7	0.0311	0.1288	88.0
7	0.6	0.0077	0.0099	79.3
8	6.3	0.0503	0.1175	125.6
9	5.1	0.0396	0.0226	128.0
10	2.7	0.0321	0.1573	83.4
11	2.8	0.0480	0.0315	57.5
12	1.2	0.0166	0.0732	72.8
13	0.9	0.0126	0.0282	67.4
14	7.7	0.0385	0.0289	200.8
15	2.4	0.0214	0.0279	114.2
16	2.5	0.0262	0.0182	94.8
17	1.6	0.0178	0.0320	91.4
18	0.7	0.0107	0.0147	69.8
19	1.8	0.0195	0.0159	92.3
20	0.4	0.0064	0.0066	60.3
21	1.8	0.0092	0.0178	199.0
22	8.2	0.0939	0.1552	87.7
23	0.8	0.0135	0.0299	60.5
24	2.3	0.0284	0.0969	82.1
25	1.3	0.0214	0.0152	60.7
26	0.9	0.0134	0.0130	64.4
27	0.9	0.0122	0.0159	74.3
28	2.4	0.0481	0.1933	49.7
29	0.7	0.0130	0.0179	55.7
30	10.0	0.0986	0.1722	101.1
31	11.6	0.2204	0.0793	52.6
32	1.3	0.0212	0.0224	60.6
33	0.7	0.0164	0.0126	42.9
34	0.6	0.0091	0.0069	68.8
35	0.7	0.0077	0.0079	90.9
36	0.0	0.0005	0.0007	43.5
37	1.5	0.0126	0.0200	117.9
38	2.0	0.0169	0.0246	119.1
39	1.4	0.0159	0.0586	84.7
40	2.3	0.0323	0.0752	70.2
41	1.6	0.021	0.0617	76.6
42	1.2	0.011	0.0316	114.3
43	1.3	0.017	0.0044	80.3
44	0.4	0.003	0.0020	116.7
45	1.0	0.017	0.0336	61.2
46	1.8	0.016	0.0123	112.5
47	6.0	0.045	0.0284	132.3
48	0.3	0.002	0.0013	125.0
49	3.1	0.022	0.0291	143.2
50	0.2	0.001	0.0021	143.5
51	1.4	0.014	0.0288	95.3
52	3.1	0.025	0.0743	126.1
53	12.0	0.115	0.3091	103.9
54	2.5	0.028	0.0557	90.1
55	8.8	0.062	0.1857	143.0
56	0.5	0.007	0.0075	71.4
57	0.8	0.007	0.0196	115.4
Total			2.86	
Average	2.73	0.030		92

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