SOURCES OF DIOXIN-LIKE COMPOUNDS AND BACKGROUND EXPOSURE LEVELS

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The United States Environmental Protection Agency (EPA) is currently reassessing the exposure to and human health/ecological impacts of dioxin and related compounds. This effort began in 1991 and is expected to be completed in late 1993. This paper describes the progress and tentative findings from this effort on sources which release these compounds to the environment and background exposure levels.

The results of a nationwide inventory of emission estimates for the U.S. are summarized in Table 1. This table lists emission estimates for the major known or suspected sources which could have releases of CDD/F (chlorinated dibenzodioxins and dibenzofurans) to the environment. The emissions are expressed in terms of 2,3,7,8-TCDD toxic equivalents (TEQ). In order to make each source emission estimate, information was required concerning both the "emission factor" term for the source (e.g., mass of contaminant released per mass of feed material processed) and the "production" term for the source (e.g., mass of feed material processed annually in the U.S.). Because the quantity and quality of the available information for both terms for each emission source varies considerably, a confidence rating scheme was developed. The scheme assigns ratings of "high", "medium", or "low" to both terms. In addition, the uncertainty in these national release estimates is reflected by presenting a possible range from a lower to upper estimate. In general, the emission estimates are quite uncertain since they were derived by extrapolating tests at only a few facilities to a nationwide basis.

Key source categories are discussed below:

- Hospital Waste Incinerators - This may be the largest source in the US. This is due to the facts that these incinerators typically do not have extensive pollution controls, number about 5000 and burn high chlorine content waste.
- Metal Smelters - The secondary smelters which recover metal from waste products such as scrap automobiles have the potential for dioxin formation due to the plastic

(and associated chlorine) in the feed material. Other countries such as Germany[1] have identified this industry as potentially important. The estimates shown in Table 1 show only moderate emissions from this source category but represent only secondary copper smelting and is based on testing at only one facility. Insufficient data are available to estimate the emissions from other secondary metal smelters or primary smelters. Accordingly, these facilities are a high priority for future emissions testing..

- Forest Fires - The possibility that forest fires could be a major source has intrigued investigators for years. Unfortunately, though very little direct emission data are available. The upper estimate shown here was made by combining total particulate generation rates with levels found in chimney soot. Dioxin levels in soot are likely to be much higher than what is actually emitted on particulates due to accumulation in chimneys. The theory that much of today's body burden could be due to natural sources (such as forest fires) has been largely discounted by testing of ancient tissues which show levels much lower than those found today[12]. Only one test[2] has been conducted that directly measured CDD/F in smoke of forest fires. Low levels were detected, but the authors caution that all or a portion of these emissions could represent resuspended material from aerial deposits rather than originally formed material.
- Wood Burning - The emission estimates for residential wood burners were made in the same fashion as described above for forest fires, ie. combining total particulate generation rates with levels found in chimney soot. Thus, they may over estimate actual emissions. The estimates for industrial wood burning were based on actual stack tests.
- Diesel Vehicles - The literature on dioxin emissions from diesel vehicles is quite limited and somewhat contradictory. A tunnel study[3] was selected as the basis for developing an upper estimate of emissions. This study is based on Norwegian fuels which may differ in composition from U.S. fuels and, although aggregate samples were collected representing hundreds of vehicles, the indirect method of analysis introduces uncertainty. The lower estimate is based on a direct tailpipe measurement involving diesel fuel in a heavy-duty Swedish vehicle[4]. This study reported no emissions at a detection limit of 100 pg/l or approximately 0.01 to 0.05 ng/km - a factor of 100 to 500 lower than the emission rate reported in the tunnel study. Because this study's results are based on only one vehicle using Swedish fuel, this emission factor is also quite uncertain. These two studies yield a very wide range of emission estimates and clearly suggests that further testing is needed.
- Municipal Waste Incinerators - The emissions from this category appear relatively low based on relatively extensive testing. It appears that the ash generated from these facilities may contain more dioxin than the stack emissions and would be important to manage carefully.
- Coal-Fired Utilities - The importance of these facilities remains unknown. Only one facility has been tested in the U.S. and no detectable levels of dioxin were found.

If dioxin was present at the detection limit, an emission factor can be estimated which suggests that these plants could collectively represent a moderately sized source. The potential importance of this source is enhanced by several factors. They are large in size and number and their high stacks indicate that they could impact very large areas.

- Pulp and Paper Mills - These facilities can have dioxin releases to water, land and paper products. The paper industry has recently made process changes which they estimate have reduced dioxin emissions by 80%. The upper estimate for water discharges (360 g TEQ/yr) was based on a 1988 survey and the lower estimate (<54 g TEQ/yr) represents conditions believed to be more representative of current release rates, though not yet independently confirmed.

The other combustor categories evaluated in this report are estimated to have much lower emissions and thus appear to be relatively minor sources on a national scale (although their local impacts could be important to evaluate). These include sewage sludge incinerators, hazardous waste incinerators, Kraft liquor boilers, drum and barrel reclaimers, tire combustors, carbon reactivation furnaces and scrap electric wire recovery facilities.

Dioxin-like compounds can also be formed during the manufacture of certain compounds such as chlorinated phenols, chlorinated benzenes and others. The releases associated with chemical manufacturing could not be quantified due to the lack of test data. Potentially such releases could occur via the product itself or as emissions to the air, land or water. Such problems have lead to the termination of production of PCBs and some phenoxy herbicides. Recently, some claims have been made that significant dioxin emissions may occur during the production of vinyl chloride monomer and associated products. However, insufficient emission data are currently available to evaluate these reports.

Several investigators have attempted to conduct "mass balance" checks on the estimates of national dioxin releases to the environment. Basically, this procedure involves comparing estimates of the emissions to estimates of aerial deposition. Such studies in Sweden[5] and Great Britain[6] have suggested that the deposition exceeds the emissions by about 10 fold. These studies are acknowledged to be quite speculative due to the strong potential for inaccuracies in emission and deposition estimates. In addition, the apparent discrepancies could be explained by long range transport from outside the country, resuspension and deposition of reservoir sources or unidentified sources. Bearing these limitations in mind, this procedure has been used here to compare the estimated emissions and deposition in the U.S.

Deposition measurements have been made at several locations in Sweden[7] and two places in the U.S.[8] These limited data suggest that a deposition rate of 1 ng TEQ/m^2-yr is typical of remote areas and that 3 ng TEQ/m^2-yr is more typical of populated areas. Applying these values, the total U.S. deposition can be estimated as 25,000 g TEQ/yr. This value is higher than the upper estimate of emissions for

Table 1. U.S. Annual Dioxin Emission Rates for Various Sources[1]

Source	Annual Emission Rate (g TEQ/yr)	Confidence Rating[2]	Ratio of Faciliites Tested to Total
Hospital Waste Incinerators	500 - 5100	M/L	7/4800
Forest Fires	300 - <3000	M/L	1/-
Industrial Wood Burning	70 - 1600	H/L	1/?
Diesel Fueled Vehicles	<8 - 870	H/L	See Note 3
Residential Wood Burning	40 - <400	H/L	1/20 million
Secondary Copper Smelting	230 - 310	H/L	1/22
Municipal Waste Incinerators	60 - 200	H/H	15/160
Sewage Sludge Incinerators	1 - 26	H/M	3/199
Hazardous Waste Incinerators	2.6 - 8.4	M/L	1/310
Kraft Black Liquor Boilers	0.9 - 5.8	H/M	3/90
Drum and Barrel Reclaimers	1.2 - 2.8	L/L	1/25

1. These emission estimates are preliminary and have not yet been peer reviewed.
2. First letter represents confidence rating for production estimate and second letter is confidence rating for emission estimate, L = Low, M = Medium and H = High.
3. Lower emission estimate is based on test of one Swedish truck and upper estimate is based on a tunnel study in Norway which represented 100's of vehicles.

Table 2. Estimated Background Exposures in the U.S.

Media	North America			
	Conc. TEQ	Contact rate	Daily intake pg/day	% of total
Soil ingestion	8.0 ppt	100 mg/day	0.8	0.7
Fish ingestion	1.2 ppt	6.5 g/day	7.8	7.3
Inhalation	0.095 pg/m^3	23 m^3/day	2.2	2.0
Water ingestion	0.0056 ppq	1.4 L/day	0.008	0.01
Milk ingestion	0.07 ppt	254 g/day	17.8	16.5
Dairy ingestion	0.36 ppt	55 g/day	19.8	18.4
Eggs ingestion	0.14 ppt	27 g/day	3.8	3.5
Beef and veal ingestion	0.48 ppt	88 g/day	42.2	39.3
Pork ingestion	0.26 ppt	28 g/day	7.3	6.8
Chicken ingestion	0.19 ppt	31 g/day	5.9	5.5
	Total		108	100