DIOXINS

SOURCE IDENTIFICATION

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Prepared for
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SUMMARY

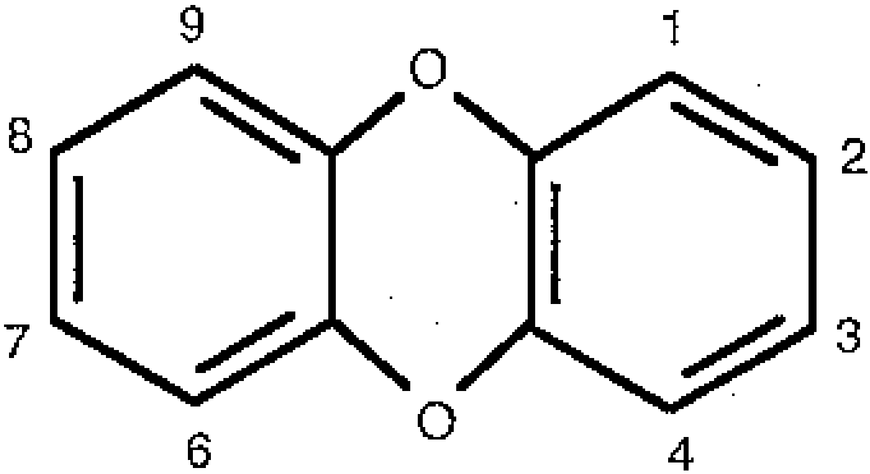
The Palo Alto Regional Water Quality Control Plant (RWQCP) conducted this study to investigate sources of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (referred to collectively as "dioxins" in this report) in the plant's influent. The goal of this effort is to identify and quantify, to the extent possible, sources of dioxins in the RWQCP influent; to identify areas where more data and analysis are needed, if any; and to identify sources that may offer the best opportunities for future pollution prevention efforts. The primary conveyances through which dioxins flow to the RWQCP appear to be laundry graywater, storm water inflow, shower water, human waste, and toilet paper. The actual sources of the dioxin conveyed to the RWQCP are local, national, and international. Primary local sources of dioxins appear to be residential wood burning and motor vehicles, particularly diesel-fueled motor vehicles. National and international activities responsible for dioxins that reach the RWQCP include bleaching paper, incinerating medical and municipal waste, and manufacture and use of chlorinated pesticides. Substantial uncertainties exist in the estimated dioxin loads; therefore, significant sources or conveyances of dioxins to the RWQCP could remain unidentified. Further study should involve continuing to monitor dioxin levels at the RWQCP; investigating the potential for dioxin contamination in chlorine-containing products; and determining dioxin levels in the supply water. Future source reduction strategies will need to focus on sources that the RWQCP does not directly control, such as dioxin emissions from diesel-fueled vehicles.

PURPOSE

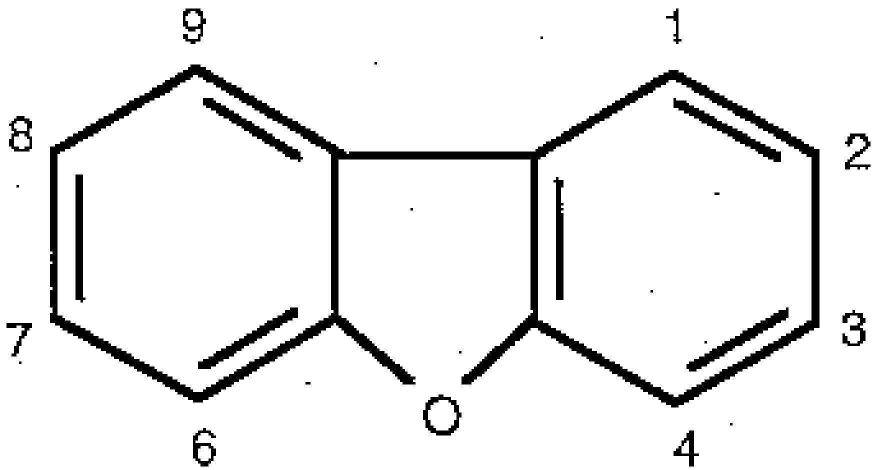
Dioxins are highly toxic substances that persist for long periods in the environment, where they bioaccumulate in living tissues. Due to their chemical properties (slow decomposition rate and low but important volatility), dioxins released to the environment can travel far from their sources. Atmospheric deposition has been observed throughout both densely and sparsely populated areas of the world (Schecter 1994). Following deposition, dioxins make their way from microorganisms to higher organisms, and as they move through the food web, their concentrations increase, accumulating especially in fatty tissues. About 96% of a typical adult's exposure to dioxins occurs through the ingestion of foods (Farland 1997). Meat, fish, and dairy products have the highest concentrations of dioxins. In humans, dioxins have been shown to cause cancer, weaken the immune system, and interfere with the endrocrine system, which is responsible for making hormones needed to regulate bodily functions, including sexual development and fertility.

The term "dioxins" commonly refers to a collection of molecules with a common chemical structure, as shown in Figure 1. PCDDs may have any number of chlorine atoms substituted at locations 1, 2, 3, 4, 6, 7, 8, or 9 (locations shown in Figure 1).

FIGURE 1: PCDDs and PCDFs



Dibenzo-*p*-dioxins (PCDDs)



Dibenzofurans (PCDFs)

PCDFs may also have any number of chlorine atoms substituted at locations 1, 2, 3, 4, 6, 7, 8, or 9. Because PCDFs share many structural and chemical characteristics with PCDDs, their inclusion is often implied when using the term "dioxins," as it is in this report. Some dioxin literature also discusses polychlorinated biphenyls (PCBs) capable of taking on the flat chemical structure typical of PCDDs and PCDFs. Although these coplanar PCBs may exhibit dioxin-like toxicity and environmental persistence, they are not addressed in this report because PCBs will be the subject of a future study planned by the RWQCP.

The chlorine atoms attached to a dioxin molecule can be in any of several different locations depending on the molecule, and many different combinations exist. Within the dioxin family of substances, each unique structure is called a "congener," and individual congeners are denoted by the locations of the chlorine atoms in the molecule. PCDDs and PCDFs consist of 210 distinct congeners. Additional dioxin-like molecules may be formed where some or all of the chlorine atoms are substituted with fluorine or bromine, elements with many properties similar to chlorine. Alternatively, sulfur atoms could replace oxygen atoms. This report does not address these substitutions because chlorine and oxygen are much more common in the environment and in the types of processes that create dioxin molecules, and because very few data exist on these molecules, their toxicities, and their presence in various environmental media.

Not all PCDD and PCDF congeners are equally toxic. The number and location of the chlorine atoms attached to these molecules determine their toxicity. The most toxic congener is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, illustrated in Figure 2. Other congeners with chlorine atoms in the 2, 3, 7, and 8 positions, regardless of how many additional chlorine atoms they may have, are also toxic. Congeners without at least four chlorine atoms located at 2, 3, 7, and 8 are relatively less toxic. The U.S. Environmental Protection Agency has adopted an internationally recognized scheme to weight each congener according to its relative toxicity. As shown in Table 1, with this scheme, quantities of various congeners can be multiplied by a Toxicity Equivalency Factor (TEF) to estimate an equivalent quantity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. When the quantities of various congeners are multiplied by their TEFs and added together, the result

FIGURE 2: 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

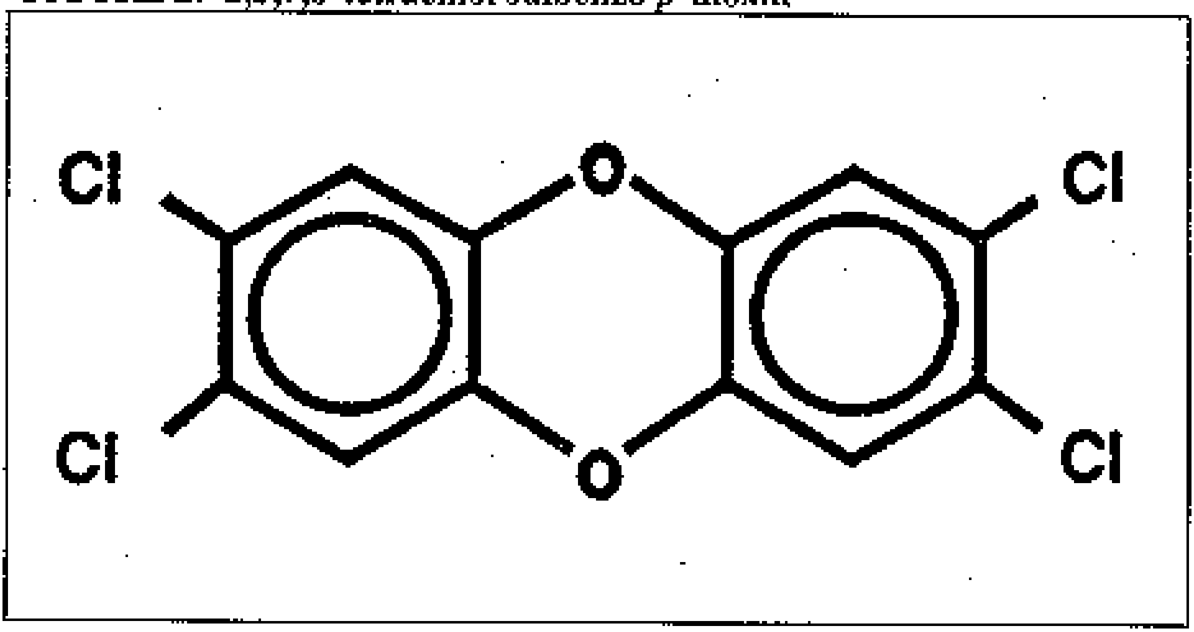


TABLE 1: Toxicity Equivalency Factors

Congener	Toxicity Equivalency Factor (TEF)
2,3,7,8-tetrachlorodibenzo-*p*-dioxin	1
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin	0.5
1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin	0.01
octachlorodibenzo-*p*-dioxin	0.001
other dibenzo-*p*-dioxins	0
2,3,7,8-tetrachlorodibenzofuran	0.1
1,2,3,7,8-pentachlorodibenzofuran	0.05
2,3,4,7,8-pentachlorodibenzofuran	0.5
1,2,3,4,7,8-hexachlorodibenzofuran	0.1
1,2,3,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,4,6,7,8-heptachlorodibenzofuran	0.01
1,2,3,4,7,8,9-heptachlorodibenzofuran	0.01
octachlorodibenzofuran	0.001
other dibenzofurans	0

Source: EPA 1994

is a Toxic Equivalent (TEQ). This study uses TEQs to the extent possible, and does not examine the relative composition of congeners, which varies from source to source.

The RWQCP releases dioxins to the environment through its treated effluent, ash from sludge incineration, and incinerator air emissions. Together, all wastewater treatment plants in the Bay Area are responsible for about 2% of the dioxins discharged directly to the bay, while most dioxins enter San Francisco Bay from air deposition of dioxin-containing particulates onto water and from storm water runoff (Tang 1997). Nevertheless, RWQCP releases are of concern because of the human and environmental toxicity of dioxins. For this reason, the RWQCP has embarked on this study to explore sources of dioxins in discharges to the sewer contributing to the plant's influent loading. Because this study focuses on the sewer system, it does not consider in-plant formation of dioxins (e.g., through low temperature formation at the plant or from the plant's sludge incinerator). The goal of this effort is to identify sources of dioxins in the RWQCP influent, estimate their relative magnitudes, identify areas where more information is needed, and provide information useful in exploring possible opportunities for pollution prevention.

RESULTS

Dioxins are produced when chlorine-containing products, such as organochlorine pesticides, polyvinyl chloride (PVC) plastics, and polychlorinated biphenyls (PCBs), are made, and when these products are heated or burned. Dioxins are not intentionally created for any useful purpose; they are waste byproducts of incineration, chemical manufacturing, and pulp and paper bleaching.

Because of the persistence of dioxins in the environment, they have been shown to disperse widely throughout the world, often depositing very far from the human activity that created them. For example, dioxins have been found far away from human populations (Schecter 1994). For this reason, some dioxins in the RWQCP service area are probably formed by human activities occurring far away. These dioxins are picked up and passed through the environment via one or more "conveyances," the last of which discharge to RWQCP, as discussed below.

Dioxin Sources -- National

Appendix A lists known sources of dioxins in the U.S. These sources include bleached chemical pulp and paper mills; chemical manufacturing, processing, and use; incineration and energy recovery; metallurgical processes; power and energy generation; and sources already present in the environment, such as pentachlorophenol-treated wood (EPA 1994). This list is not exhaustive. Other dioxin sources include the manufacture of graphite electrodes used in the chloralkali industry; the production and recycling of magnesium, nickel, and aluminum; and petroleum refining (Schecter 1994). Nationally, most dioxin is released to air as a result of municipal and medical waste incineration, cement manufacturing, wood burning, copper smelting, coal combustion, open burning (e.g., forest fires), motor vehicle operation, and pentachlorophenol wood treatment (Bateman and Deboisblanc 1996).

Dioxin Sources -- Local

Very few major dioxin sources are located within the RWQCP service area. For example, no incinerators, chemical manufacturers, or pulp or paper bleaching operations discharge dioxins directly to the RWQCP. Sources of dioxins in the San Francisco Bay Area include motor vehicles, residential wood burning, and other smaller sources. As shown in Appendix B, residential wood burning accounts for 15% of dioxin air emissions in the Bay Area. Diesel-fueled motor vehicles are responsible for about 69% of local dioxin emissions (Bateman and Deboisblanc 1997).

Dioxin Sources -- RWQCP

The dioxin concentration in RWQCP influent is extremely low and difficult to measure. On the basis of analytical sampling, however, the concentration is believed to be between 7×10^{-8} and 200×10^{-8} pounds per day (lb/day) TEQ. The RWQCP's best estimate of the actual concentration is about 20 x 10^{-8} lb/day TEQ, but this estimate is highly uncertain as discussed below.

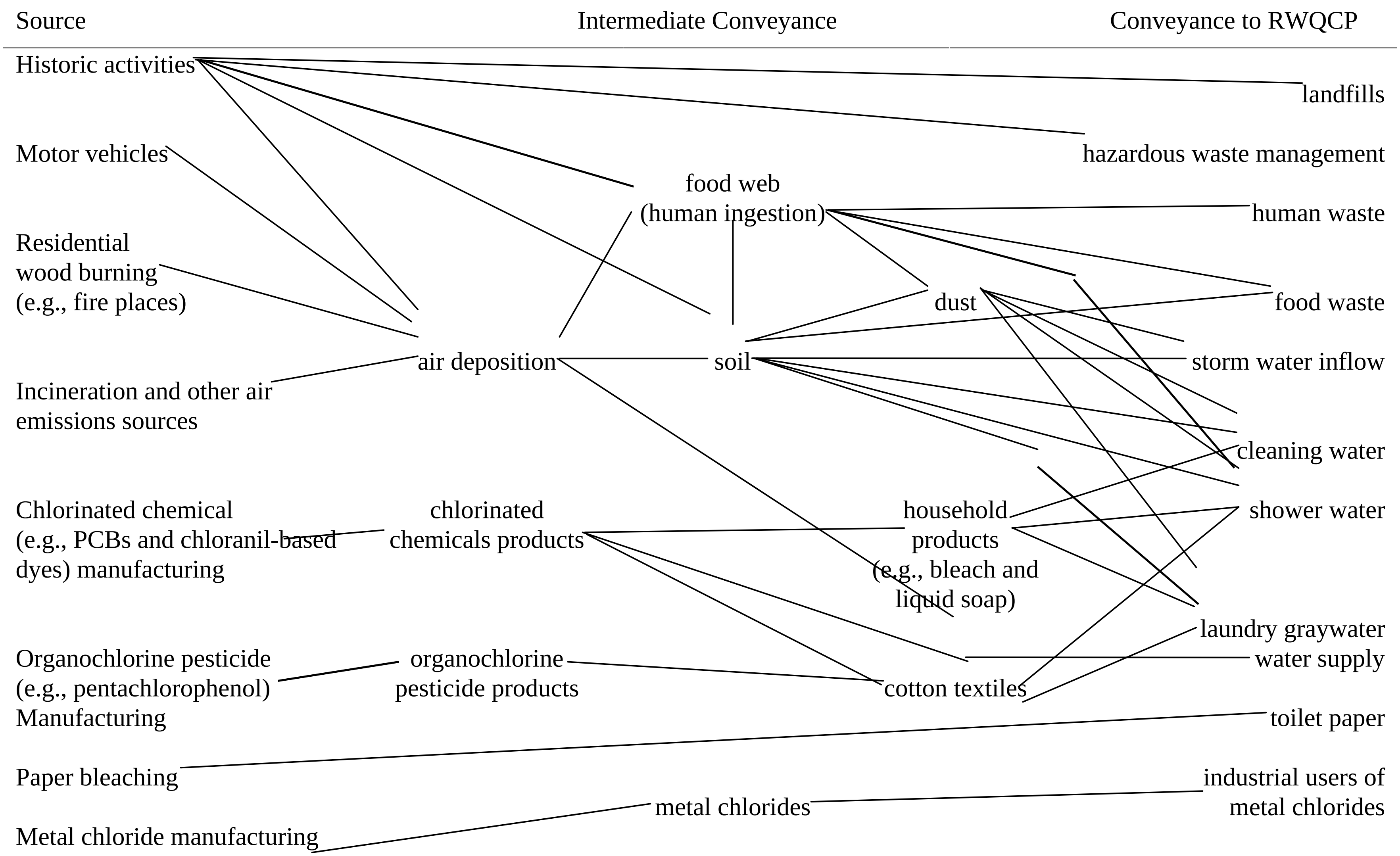
In most cases, the primary dioxin sources (where dioxins are created) do not release dioxins directly to the RWQCP; dioxins arrive at the plant through several indirect routes or conveyances. Figure 4 illustrates the major conveyances through which dioxins reach the RWQCP. As shown in this figure, conveyances to the RWQCP can be linked to intermediate conveyances that lead back to the original sources of the dioxins. As mentioned above, most of these original sources do not exist within the RWQCP service area to any appreciable extent.

Table 2 categorizes each conveyance to the RWQCP as either a relatively large contributor to the RWQCP's dioxin load or a relatively small contributor. To the extent possible, these conclusions are based on calculations of estimated dioxin loads from each conveyance (see Appendices C and D). As discussed below, these load estimates are highly uncertain. Nevertheless, they indicate that the greatest conveyances of dioxins to the RWQCP are probably laundry graywater, storm water inflow, shower water, human waste (particularly feces), and bleached toilet paper. By tracing these conveyances back to the original dioxin sources shown in Figure 4, metal chloride manufacturing and historic activities can be eliminated as potentially substantial sources of dioxins in the RWQCP influent. Dioxin air emissions sources and organochlorine pesticide use can be linked to all of the large conveyances to the RWQCP, except for toilet paper, which may contain dioxins from the bleaching process performed by some manufacturers. Table 3 matches the large conveyances to the RWQCP to the most important sources of dioxins conveyed through these routes.

The importance of atmospheric deposition as an intermediate conveyance of dioxins to the RWQCP is evident in Figure 4. Dioxins emitted by many sources disperse in the atmosphere, mix with dioxins from other sources, and eventually deposit on soil and water surfaces. These deposits contaminate the soil and water, thereby contaminating storm water runoff and entering the food web. Dioxins accumulated in the food web return to the environment through animal waste, including human waste. Presumably, dioxins accumulated within the body and on the skin can also be released to shower water and household dust as dead skin cells are released (Wittsiepe et al. 1997).

As Figure 4 shows, a second important intermediate conveyance is the use of pentachlorophenol. Commercial pentachlorophenol contains various dioxin contaminants (Baird 1995), and textiles made of cotton grown in certain parts of the world outside the U.S. have been shown to contain dioxins, apparently due to the treatment of raw cotton with pentachlorophenol. Trace amounts of dioxins in this cotton clothing are believed to be a source of dioxins in laundry graywater. Chloranil-based dyes, such as carbazole violet, and fabric bleaching processes may also contribute dioxins to laundry graywater (Fiedler 1993; Remmes et al. 1992; Lexén et al. 1993). Dioxins in clothing are believed to enter the upper layers of human skin, then wash off during showers, contributing to elevated dioxin levels in shower water (Horstmann and McLachlan 1994).

Figure 4. Major Sources of Dioxins and their Primary Routes to the RWQCP



SOURCE: EIP Associates, 1997

TABLE 2: Estimated Dioxin Loads

Conveyance to RWQCP	Estimated Load (10^{-8} lb/day TEQ)[a]	Uncertainty of Data	Contribution to RWQCP Load[b]
Laundry Graywater	60	Very High	LARGE
Storm Water Inflow	6	High	LARGE
Human Waste	4	High	LARGE
Shower Water	4	Very High	LARGE
Toilet Paper	2	Very High	LARGE
Food Waste	0.7	High	LARGE
Landfills	0.02 to 0.2	High	small
Hazardous Waste Management	0.01 to 0.1	High	small
Industrial Use of Metal Chlorides	0.05	Very High	small
Cleaning Water (at residential and commercial facilities)[c]	NA	--	small
Liquid Soap	0.2	Very High	small
Chlorine Bleach	0.002	Very High	small
Water Supply	NA	--	Unknown
TOTAL	7 to 200	High	--

NA, Not Available

[a] See Appendices C and D.

[b] For purposes of this report, a relatively large contribution to the RWQCP load is defined as at least 10% of the lowest estimated load.

[c] Although no quantitative estimate of dioxin levels in cleaning water is available, the intermediate conveyances and sources of dioxins in cleaning water would be generally similar to those in storm water, with the exception of cleaning products added for indoor uses. Because the cleaning water flow to the RWQCP is much less than the volume of storm water inflow, however, the importance of this conveyance is believed to be relatively small.

UNCERTAINTIES

Each estimated dioxin load presented in Table 2 is evaluated according to the uncertainty of the data. Because all of these estimates are subject to substantial uncertainty, they are categorized as either exhibiting “high uncertainty” or “very high uncertainty,” as defined below.

- ***High Uncertainty:*** Calculation is based on very limited data and numerous assumptions. Data may be obtained from a poorly documented source. Treatment of “non-detect” data may contribute greatly to uncertainty. Error could be greater than ±100%.

TABLE 3: Large Dioxin Conveyances and their Primary Sources

Large Conveyances to RWQCP	Most Important Sources
Laundry Graywater and Shower Water	Chlorinated Chemical Manufacturing and Organochlorine Pesticide Manufacturing *(e.g., via chloranil-based dyes, pentachlorophenol-treated cotton textiles, chlorine bleach, and soil)*
Storm Water Inflow	Motor Vehicles, Residential Wood Burning, Incineration, and Historic Activities *(via air deposition and soil)*
Human Waste and Food Waste	Motor Vehicles, Residential Wood Burning, Incineration, and Historic Activities *(via air deposition, soil, and food web)*
Toilet Paper	Paper Bleaching

- ***Very High Uncertainty:*** Calculation is based on interpretation of a poorly documented source (or a foreign source that may not be representative of conditions in the RWQCP service area) and numerous important, yet uncertain, assumptions. Error could be more than one order of magnitude.

RWQCP Influent Load Estimate

The RWQCP has collected four 24-hour composite samples from the plant's influent, and measured the concentrations of each of the 17 dioxin congeners for which a TEF exists (as shown in Table 1, only 17 of the 210 dioxin congeners have TEFs). As mentioned above, the dioxin concentration in the RWQCP influent is extremely low and challenging to measure. Available technologies can detect some dioxin congeners at these very low concentrations, but quantification is difficult.

The resulting uncertainty arises from the individual measurements being close to their detection limits, which range from 8 x 10^{-13} to 6 x 10^{-12} grams per liter. Substantial uncertainty also results from frequent "non-detects." Of the 17 congeners studied, the only 4 congeners detected in the plant's influent are 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin; octachlorodibenzo-*p*-dioxin; 1,2,3,4,6,7,8-heptachlorodibenzofuran; and octachlorodibenzofuran. The treatment of "non-detect" data for the other congeners greatly affects the results of the calculations.

Assuming that the concentrations of all congeners not detected through the sampling effort are zero, the dioxin concentration in the RWQCP's influent is estimated to be about 7 x 10^{-8} lb/day TEQ. Assuming that the concentrations of all undetected congeners are equal to their detection limits, the dioxin concentration in the RWQCP's influent is estimated to be about 200 x 10^{-8} lb/day TEQ. The actual influent dioxin concentration is believed to be somewhere within this range, which spans two orders of magnitude.

To estimate the congener concentrations that could exist in the influent without being detectable, the RWQCP used measured dioxin concentrations in the plant's sludge cake, where all but 3 of the 17 congeners with TEFs were detected. Because most of the dioxin in the influent is expected to be absorbed and concentrated in this cake, the relative proportions among the various congeners in the cake are believed to be representative of the relative proportions in the influent. Again, the treatment of "non-detects" data significantly affects the results of the calculated dioxin concentration, and this process is subject to considerable professional judgment. With this caveat, the RWQCP's best estimate of the dioxin concentration in its influent is 20 x 10^{-8} lb/day TEQ.

Interpreting these Results

Because of the uncertainty of the results summarized in Table 2, they could be subject to over-interpretation. By categorizing each conveyance as either large or small, this report avoids inappropriately comparing the individual results with one another. Each estimate provided in Table 2 is subject to sufficient uncertainty that the estimates should *not* be added together to estimate the total contribution of the known dioxin conveyances. In fact, the estimated dioxin loads from the conveyances listed in Table 2 may sum to a value substantially greater than the actual dioxin load at the plant. Alternatively, the individual conveyances could fail to account for a substantial portion of the measured dioxin load. Because the total dioxin load in the RWQCP influent cannot be determined with certainty, the amount of dioxin flowing to the RWQCP from unidentified conveyances cannot be estimated.

RECOMMENDATIONS

On the basis of the results presented in this report, the RWQCP may wish to pursue some of the following suggestions for further study.

- Continue to monitor dioxin levels at various locations throughout the plant. An improved understanding of how much dioxin moves through the plant and where it goes will facilitate comparisons among the sources and conveyances identified in this source investigation.

- Investigate dioxin concentrations in the water supply, and if substantial, investigate the source of this contamination (e.g., water treatment chemicals or atmospheric deposition on reservoirs).

- Investigate dioxin levels in toilet paper and the source of dioxins in toilet paper.

- Determine which chlorinated chemical products, including organochlorine pesticides, may contain dioxin as a contaminant, and investigate the contaminant concentrations and service area use of these products.

- Develop a dioxin pollution prevention plan that addresses the significant dioxin sources contributing to RWQCP loads.

- Explore ways to encourage the reduction of dioxins emissions in diesel vehicle exhaust.

- Consider ways to discourage the use of dioxin-contaminated dyes and pesticides on textiles used to make clothing.

REFERENCES

The following references are cited in this report. Appendix E contains a bibliography of additional information sources pertaining to dioxins and related issues.

Association of Bay Area Governments (ABAG), *Projections '96: Forecasts for the San Francisco Bay Area to the Year 2015*, December 1995.

Baird, C., *Environmental Chemistry*, W. H. Freeman and Company, U.S.A., 1995.

Bateman, B., and B. Deboisblanc, Toxic Evaluation Section, Bay Area Air Quality Management District, *Air Emissions of Dioxins in the Bay Area*, March 27, 1996.

Beck, H., K. Eckart, W. Mathar, and R. Wittkowski, "Occurrence of PCDD and PCDF in Different Kinds of Paper," *Chemosphere*, **17**(1):51-57, 1988.

California Regional Water Quality Control Board, San Francisco Bay Region (CRWQCB), *Survey of Storm Water Runoff for Dioxins in the San Francisco Bay Area*, February 1997.

City and County of San Francisco (CCSF) Department of Public Works Clean Water Program, *Consumer Products Heavy Metals Inventory*, August 1991.

Farland, W. H., National Center for Environmental Assessment, U.S. Environmental Protection Agency, “Workshop on Dioxin and Dioxin-like Compounds,” presentation at a workshop meeting of the San Francisco Bay Regional Water Quality Control Board, May 7, 1997.

Fiedler, H., “Formation and Sources of PCDD/PCDF,” *Organohalogen Compounds*, **11**:221-228, 1993.

Heindl, A., and O. Hutzinger, “Search for Industrial Sources of PCDD/PCDFs: II. Metal Chlorides,” *Chemosphere*, **15**(5):653-658, 1986.

Horstmann, M., and M. McLachlan, “Textiles as a Source of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD/F) in Human Skin ;and Sewage Sludge,” *Environmental Science and Pollution Research*, **1**(1):15-20, 1994.

Horstmann, M., and M. McLachlan, “Concentrations of Polychlorinated Dibenzo-p-Dioxins (PCDD) and Dibenzofurans (PCDF) in Urban Runoff and Household Wastewaters,” *Chemosphere*, **31**(3):2887-2896, 1995.

Larry Walker Associates (LWA), *Residential Metals Study*, prepared for the Central Contra Costa Sanitary District, May 1994.

Larry Walker Associates (LWA), “Dioxin Loads from Food and Human Wastes,” memorandum, August 18, 1997. (See Appendix D.)

LeBel, G., D. Williams, and F. Benoit, “Chlorinated Dibenzodioxins and Dibenzofurans in Consumer Paper Products,” *Chemosphere*, **25**(11):1683-1690, 1992.

Leinweber, G., Environmental Safety Manager, City of Mountain View Fire Department, telephone conversation, August 26, 1997.

Lexén, K., C. Wit, B. Jansson, L. Kjeller, S. Kulp, K. Ljung, G. Söderström, and C. Rappe, “Polychlorinated Dibenzo-p-dioxin and Dibenzofuran Levels and Patterns in Samples from Different Swedish Industries Analyzed within the Swedish Dioxin Survey,” *Chemosphere*, **27**(1-3):163-170, 1993. 1993.

Palo Alto Regional Water Quality Control Plant (RWQCP), *Clean Bay Plan 1997*, 1997.

Poiger, H., and C. Schlatter, “Pharmacokinetics of 2,3,7,8-TCDD in Man,” *Chemosphere*, **15**(9-12):1489-1494, 1986.

Rappe, C., R. Andersson, K. Lundström, and K. Wiberg, "Levels of Polychlorinated Dioxins and Dibenzofurans in Commercial Detergents and Related Products," *Chemosphere*, **21**(1-2):43-50, 1990.

Remmes, J., A. Dupuy, D. McDaniel, R. Harless, and D. Steele, "Polychlorinated Dibenzo-p-dioxin and Dibenzofruran [sic] Contamination in Chloranail [sic] and Carbazole Violet," *Chemosphere*, **25**(7-10):1505-1508, 1992.

Schecter, A., *Dioxins and Health*, Plenum Press, New York, 1994.

Tang, L., San Francisco Bay Regional Water Quality Control Board, "Workshop on Dioxin and Dioxin-like Compounds," presentation at a workshop meeting of the San Francisco Bay Regional Water Quality Control Board, May 7, 1997.

U.S. Environmental Protection Agency (EPA), *Estimating Exposure to Dioxin-Like Compounds* (Review Draft), EPA/600/6-88/005Ca, June 1994. (EPA released this review draft as part of its continuing scientific reassessment of the health risks posed by dioxins and dioxin-like compounds. Although the final report has not been formally released, the draft provides a useful summary of information available at this time.)

Wittsiepe, J., U. Ewers, P. Schrey, and F. Selenka, "PCDD/F in House Dust" (http://www.hygiene.ruhr-uni-bochum.de), 1997.

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APPENDIX A

Sources of Dioxins in the U.S.

DIOXINS RELEASED IN THE U.S., BY MEDIUM

Emission Source	Emission Rate (grams/year TEQ)			
	Air	Water	Land	Product
Industrial / Municipal Processes				
Bleached Chemical Pulp and Paper Mills	(a)	110	100	150
Publicly Owned Treatment Works	(b)	--	210	3.6
Chemical Manufacturing / Processing / Use Sources:				
Chlorophenols	--	NEG	NEG	--
Chlorobenzene	--	NEG	NEG	--
Aliphatic Chlorine Compounds		NEG	--	--
Dioxazine Dyes / Pigments	--	--	--	--
Pesticides	--	--	--	--
Combustion and Incineration Processes				
Incineration and Energy Recovery:				
Municipal Waste Incineration	3,000	NEG	1,800	NA
Hazardous Waste Incineration	35	NEG	--	NA
Medical Waste Incineration	5,100	NEG	--	NA
Kraft Black Liquor Boilers	2.7	NEG	--	NA
Sewage Sludge Incineration	23	NEG	--	NA
Carbon Reactivation Furnaces	0.1	NEG	NA	NA
Cement Kilns	350	--	24	--
Metallurgical Processes:				
Ferrous Metal Smelting / Refining	--	--	--	NEG
Secondary Copper Smelting / Refining	230	--	--	NEG
Secondary Lead Smelting / Refining	1.6	--	--	NEG
Scrap Electric Wire Recovery	NEG	NEG	NEG	NEG
Drum and Barrel Reclamation	1.7	--	--	NEG
Power / Energy Generation:				
Tire Combustion	0.3	--	--	NA
Vehicle Fuel Combustion (leaded)	(c)	NA	NA	NA
Vehicle Fuel Combustion (unleaded)	1.3	NA	NA	NA
Vehicle Fuel Combustion (diesel)	85	NA	NA	NA
Wood Burning (residential)	40	NA	--	NA
Wood Burning (industrial)	320	--	--	NA
Coal Combustion (residential)	--	--	--	NA
Coal Combustion (industrial)	--	NA	--	NA
Coal Combustion (utility)	--	--	--	NA
Oil Combustion (residential)	--	NA	--	NA
Charcoal Briquette Combustion (residential)	--	NA	--	NA
Reservoir Sources:				
Pentachlorophenol-Treated Surfaces	--	--	--	--
Forest Fires (d)	86	--	--	NA
TOTAL (e)	9,300	110	2,100	150

NA: Not Applicable NEG: Negligible or Non-Existent BLANK (--): Insufficient Data

(a) See Kraft black liquor boilers, below.
(b) See sewage sludge incineration, below.
(c) Leaded fuel production and the manufacture of motor vehicles requiring leaded fuel are prohibited in the U.S.
(d) The fraction of the estimated emissions from forest fires representing a reservoir source is unknown.
(e) The total reflects only the emissions estimates shown here. The number of blanks reflects the many unknowns.

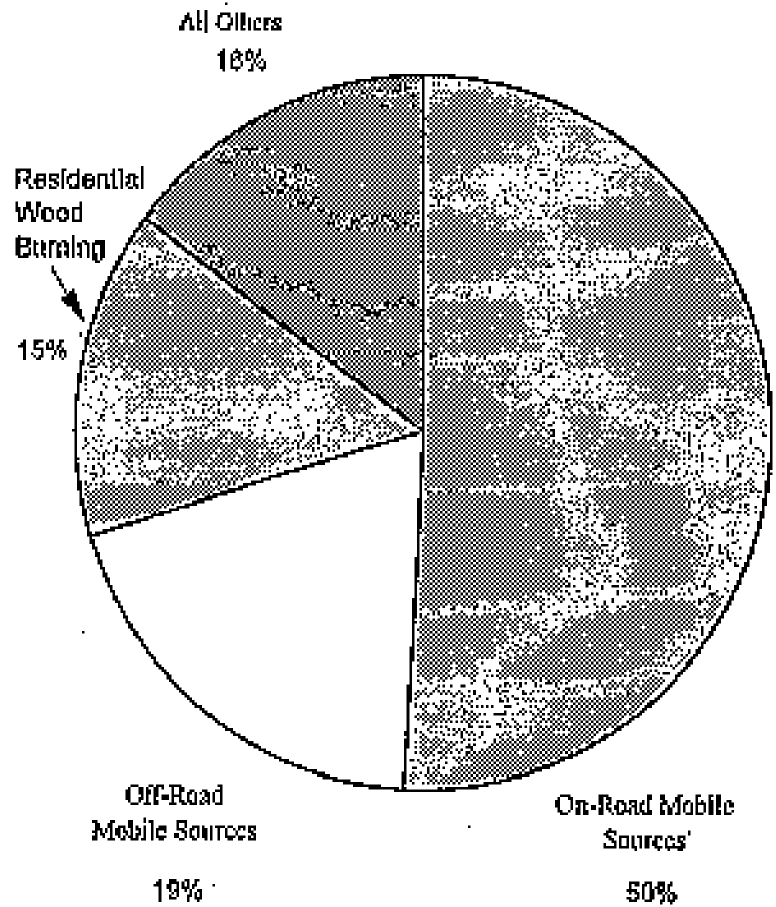
SOURCE: EPA 1994

APPENDIX B

Local Sources of Dioxins in Air

(from Bateman, B., and B. Deboisblanc, Toxic Evaluation Section, Bay Area Air Quality Management District, *Air Emissions of Dioxins in the Bay Area*, March 27, 1996)

Source Category	Dioxin Emissions (g TEQ/yr)
On-Road Mobile Sources	1.444
Off-Road Mobile Sources	0.558
Residential Wood Combustion	0.424
Landfill Gas Combustion	0.176
Fires	0.097
Hazardous Waste Incineration	0.063
Iron and Steel Foundries	0.033
Cement Kilns	0.018
Petroleum Refining Catalyst Regeneration	0.050
Sewage Sludge Incineration	0.012
Drum Reclamation Furnaces	0.009
Medical Waste Incineration	0.005
Coal and Coke Combustion	0.006
Industrial Wood Waste Incineration	0.002
Crematories	<0.001
Total:	2.90



APPENDIX C

Calculations

LAUNDRY GRAYWATER

Average dioxin concentration in laundry graywater = 22.75×10^{-12} g/l TEQ
(*Source:* Horstmann and McLachlan 1995)

Palo Alto RWQCP service area households = 81,290
Palo Alto RWQCP service area population = 236,200
(*Source:* ABAG 1995)

Central Contra Costa Sanitary District households = 110,000
Central Contra Costa Sanitary District service area population = 384,615
(*Source:* LWA 1994)

Average volume of laundry graywater discharged by Central Contra Costa Sanitary District households = 300 gal /week (*Source:* LWA 1994)

Persons per household in Palo Alto RWQCP service area =
$236{,}200 \div 81{,}290 = 2.91$

Persons per household in Central Contra Costa Sanitary District service area =
$384{,}615 \div 110{,}000 = 3.50$

Average volume of laundry graywater discharged by Palo Alto RWQCP households =
300 gal /week/household x $(2.91 \div 3.50)$ = 249 gal/week/household
249 gal/week/household $\div$ 7 days/week = 35.6 gal/day/household
35.6 gal/day/household x 81,290 households = 2.90×10^{6} gal/day

22.75×10^{-12} g/l TEQ x 3.785 l/gal x 2.90×10^{6} gal/day x 2.205×10^{-3} lb/g =
5.5×10^{-7} lb/day TEQ

Notes:

The concentration reported in the literature is based on 4 samples representing 4 loads of laundry collected in Germany. "Non-detects" were taken to equal detection limits, which ranged from 0.5 to 1 pg/l. Of the 17 congeners for which TEFs exist, between 14 and 16 were detected in each sample. Only 1,2,3,7,8,9-hexachlorodibenzofuran was not detected in any sample.

STORM WATER INFLOW

Average dioxin concentration in storm water = 8.72×10^{-12} g/l TEQ
(*Source:* CRWQCB 1997)

RWQCP infiltration and inflow = 1.7×10^{6} gal/day
(*Source:* RWQCP 1997)

Assuming half of infiltration and inflow is inflow,
1.7×10^{6} gal/day ÷ 2 = 8.5×10^{5} gal/day

8.72×10^{-12} g/l TEQ x 3.785 l/gal x 8.5×10^{5} gal/day x 2.205×10^{-3} lb/g =
6.2×10^{-8} lb/day TEQ

Notes:

The concentration is based on 15 samples from 6 sites collected throughout the San Francisco Bay Area. "Non-detects" were taken to equal zero; detection limits ranged from 0.76 to 10 pg/l, depending on the congener and sample considered. Of the 17 congeners for which TEFs exist, between 4 and 15 were detected in each sample.

HUMAN WASTE (Feces and Urine)

Dioxin excreted in feces = 3.1×10^{-8} lb/day TEQ
(*Source:* LWA 1997)

Dioxin excreted in urine = 28% dioxin excreted in feces
(*Source:* Poiger and Schlatter 1986)

28% of 3.1×10^{-8} lb/day TEQ = 8.7×10^{-9} lb/day TEQ in urine

8.7×10^{-9} lb/day TEQ in urine + 3.1×10^{-8} lb/day TEQ in feces =
$\mathbf{4.0 \times 10^{-8}}$ lb/day TEQ in human waste

Notes:

The concentration in feces was estimated by Larry Walker Associates (LWA 1997, see Appendix D). The concentration in urine was estimated on the basis of reported excretion by a rhesus monkey. Little information is provided to support this value, which is the ratio of urinary excretion to fecal excretion.

SHOWER WATER

Average mass of dioxin in water from one shower = 74.8×10^{-12} g TEQ
(*Source:* Horstmann and McLachlan 1995)

Palo Alto RWQCP service area population = 236,200
(*Source:* ABAG 1995)

Assuming that each person takes one shower per day,
74.8×10^{-12} g TEQ / person x 236,200 persons / day x 2.205×10^{-3} lb/g =
3.9×10^{-8} lb/day TEQ

Notes:

The concentration reported in the literature is based on 5 samples collected in Germany. "Non-detects" were taken to equal detection limits, which ranged from 2 to 35 pg/shower, depending on the congener. Of the 17 congeners for which TEFs exist, between 7 and 11 were detected in each sample.

TOILET PAPER

Dioxin concentration in tissue paper = 4.42×10^{-12} grams TEQ/grams paper
(*Source:* LeBel et al. 1992)

Average consumption of toilet paper (toilet tissue) = 8.48 g/person/day
(*Source:* CCSF 1991)

Palo Alto RWQCP service area population = 236,200
(*Source:* ABAG 1995)

8.48 g/person/day x 236,200 persons x 4.42×10^{-12} grams TEQ/grams paper
x 2.205×10^{-3} lb/g = $\mathbf{2.0 \times 10^{-8}}$ lb/day TEQ

Notes:

LeBel et al. measured the dioxin concentrations of 14 tissue paper products in Ontario, Canada (average = 4.42 ppt). Of these, only 3 were toilet papers (average = 3.1 ppt) (LeBel et al. 1992). Because of the variability of the data and because Beck et al. report a higher concentration for "cosmetic tissue" in Germany (4.7 ppt) (Beck et al. 1988), the average value for all tissue paper as reported by LeBel et al. is used here. "Non-detects" were taken to equal zero; the detection limits ranged from 0.2 to 0.7 pg/g. Of the 17 congeners for which TEFs exist, between 3 and 9 were detected in each sample.

LANDFILLS

The RWQCP collected three grab samples of landfill discharges: one from the Palo Alto landfill, one from the Mountain View landfill, and one from the condensate from the Palo Alto landfill-associated cogeneration facility.

Palo Alto Landfill

The concentrations of each of the 17 dioxin congeners of interest (those for which a TEF exists) were measured with detection limits ranging from 9.2×10^{-13} to 2.6×10^{-12} grams per liter, depending on the congener. Of the 17 congeners studied, only 4 were detected: 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin; octachlorodibenzo-*p*-dioxin; 1,2,3,4,6,7,8-heptachlorodibenzofuran; and octachlorodibenzofuran. Assuming that "non-detects" equal zero, the dioxin concentration in the Palo Alto landfill discharge was about 6.9×10^{-13} g/l TEQ. With a discharge flow of 11,679 gal/day, this concentration corresponds to a dioxin load of about 6.7×10^{-11} lb/day TEQ. When "non-detects" were taken to equal the detection limits, the dioxin concentration were estimated to be about 6.0×10^{-12} g/l TEQ, for a load of 5.9×10^{-10} lb/day TEQ.

Mountain View Landfill

The concentrations of each of the 17 dioxin congeners of interest were measured with detection limits ranging from 1.1×10^{-12} to 2.6×10^{-12} grams per liter. Of the 17 congeners studied, only 4 were detected: 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin; octachlorodibenzo-*p*-dioxin; 1,2,3,4,6,7,8-heptachlorodibenzofuran; and octachlorodibenzofuran. Assuming that "non-detects" equal zero, the dioxin concentration in the Mountain View landfill discharge was about 5.9×10^{-13} g/l TEQ. With a discharge flow of about 24,000 gal/day, this concentration corresponds to a dioxin load of about 1.2×10^{-10} lb/day TEQ. When "non-detects" were taken to equal the detection limits, the dioxin concentration was estimated to be about 6.2×10^{-12} g/l TEQ, for a load of 1.3×10^{-9} lb/day TEQ.

Cogeneration Facility

The concentrations of the 17 dioxin congeners were measured with detection limits ranging from 4.7×10^{-13} to 3.0×10^{-12} grams per liter. Of the 17 congeners studied, only 1 was detected: octachlorodibenzo-p-dioxin. Assuming that "non-detects" equal zero, the dioxin concentration in the cogeneration facility discharge was about 1.7×10^{-14} g/l TEQ. With a discharge flow of about 50 gal/day, this concentration corresponds to a dioxin load of about 7.1×10^{-15} lb/day TEQ. When "non-detects" were taken to equal the detection limits, the dioxin concentration was estimated to be about 4.5×10^{-12} g/l TEQ or 1.9×10^{-12} lb/day TEQ.

Total Landfill Discharge Load

"Non-Detects" = Zero:
$6.7 \times 10^{-11} + 1.2 \times 10^{-10} + 7.1 \times 10^{-15} = \mathbf{1.9 \times 10^{-10}}$ lb/day TEQ

"Non-Detects" = Detection Limits:
$5.9 \times 10^{-10} + 1.3 \times 10^{-9} + 1.9 \times 10^{-12} = \mathbf{1.9 \times 10^{-9}}$ lb/day TEQ

HAZARDOUS WASTE MANAGEMENT

The RWQCP collected one grab sample from Romic Environmental Technology Corporation's hazardous waste management facility in East Palo Alto. The concentrations of each of the 17 dioxin congeners of interest (those for which a TEF exists) were measured with detection limits ranging from 7.2×10^{-13} to 3.3×10^{-12} grams per liter, depending on the congener. Of the 17 congeners studied, only 4 were detected: 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin; octachlorodibenzo-*p*-dioxin; 1,2,3,4,6,7,8-heptachlorodibenzofuran; and octachlorodibenzofuran. Assuming that "non-detects" equal zero, the dioxin concentration in the hazardous waste management discharge was about 5.7×10^{-13} g/l TEQ. With a discharge flow of about 20,000 gal/day, this concentration corresponds to a dioxin load of about **9.5×10^{-11}** lb/day TEQ. When "non-detects" were taken to equal the detection limits, the dioxin concentration was estimated to be about 6.7×10^{-12} g/l TEQ or **1.1×10^{-9}** lb/day TEQ.

INDUSTRIAL USE OF METAL CHLORIDES

Estimated dioxin contamination in metal chlorides (*Source:* Heindl and Hutzinger 1986):

Ferric Chloride ($FeCl_3$) -- 0.162 ppb TEQ = 1.6×10^{-10}
Cupric Chloride ($CuCl_2$) -- 0.00243 ppb TEQ = 2.43×10^{-12}
Aluminum Chloride ($AlCl_3$) -- 0.035 ppb TEQ = 3.5×10^{-11}

Industrial use of metal chlorides in Mountain View (*Source:* Leinweber 1997):

Ferric Chloride ($FeCl_3$) -- 184 gal solution
Cupric Chloride ($CuCl_2$) -- 780 gal solution
Aluminum Chloride ($AlCl_3$) -- 10 lb

Assuming that the solutions contain 30% metal chloride
and that the density of the solutions is equal to the density of water,
dioxin TEQ at industries in Mountain View:

Ferric Chloride ($FeCl_3$)

184 gal solution x 3.785 l/gal x 1,000 g/l x 2.205×10^{-3} lb/g x 0.3 $FeCl_3$/solution x 1.6×10^{-10} TEQ/$FeCl_3$ = 7.4×10^{-8} lb TEQ

Cupric Chloride ($CuCl_2$)

780 gal solution x 3.785 l/gal x 1,000 g/l x 2.205×10^{-3} lb/g x 0.3 $CuCl_2$/solution x 2.43×10^{-12} TEQ/$CuCl_2$ = 4.7×10^{-9} lb TEQ

Aluminum Chloride ($AlCl_3$)

10 lb $AlCl_3$ x 3.5×10^{-11} TEQ/$AlCl_3$ = 3.5×10^{-10} lb TEQ

Total TEQ in Mountain View Industries =
7.4×10^{-8} lb TEQ + 4.7×10^{-9} lb TEQ + 3.5×10^{-10} lb TEQ = 7.9×10^{-8} lb TEQ

Assuming that the entire RWQCP service area contains about twice as much of these solutions as in Mountain View alone,
and that 10% is discharged to the RWQCP
(the rest goes to other media, as would be the case with $FeCl_3$ used as flocculent),
and that the amount on site is a one month supply,
dioxin discharge to the RWQCP:

7.9×10^{-8} lb TEQ x 2 x 0.1 ÷ 30 days = **5.3×10^{-10}** lb/day TEQ

Notes:

The concentration data are based on a study completed in Germany. Information is reported for 4 congener groups: heptachlorodibenzo-*p*-dioxin, octachlorodibenzo-*p*-dioxin, heptachlorodibenzofuran, and octachlorodibenzofuran. Congener-specific information is not reported. To estimate the TEQ, results for heptachlorodibenzo-*p*-dioxin and heptachlorodibenzofuran were multiplied by the TEFs for 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin and 1,2,3,4,6,7,8-heptachlorodibenzofuran. “Non-detects” were taken to equal zero; the detection limit for all congeners was 20 ppt.

LIQUID BLEACH

Dioxin concentration in liquid chlorine bleach = 3.9×10^{-12} grams TEQ/liter bleach
(*Source:* Rappe et al. 1990)

Average consumption of liquid bleach = 12.05 g/person/day
(*Source:* CCSF 1991)

Palo Alto RWQCP service area population = 236,200
(*Source:* ABAG 1995)

12.05 g/person/day x 236,200 persons x 3.9×10^{-12} grams TEQ/liter bleach
x 2.205×10^{-3} lb/g x 0.001 liters bleach/gram bleach = **2.4×10^{-11}** lb/day TEQ

Notes:

The concentration reported in the literature is 4.9 pg/l TEQ, but on the basis of the published data for each congener, the correct value appears to be 3.9 pg/l TEQ. The result is based on 1 sample. "Non-detects" were taken to equal zero; the detection limits ranged from 0.2 to 20 pg/l, depending on the congener. Of the 17 congeners for which TEFs exist, 5 were detected.

LIQUID SOAP

Dioxin concentration in liquid soap = 447×10^{-12} grams TEQ/liter soap
(*Source:* Rappe et al. 1990)

Average consumption of liquid soap = 6.58 g/person/day
(*Source:* CCSF 1991)

Palo Alto RWQCP service area population = 236,200
(*Source:* ABAG 1995)

6.58 g/person/day x 236,200 persons x 447×10^{-12} grams TEQ/liter soap
x 2.205×10^{-3} lb/g x 0.001 liters soap/gram soap = **1.5×10^{-9}** lb/day TEQ

Notes:

The consumption rate of liquid soap is unknown, but it is assumed to be greater than the consumption rate for liquid dish detergent (6.58 grams/person/day) or bath soap (3.25 grams/person/day) (CCSF 1991). Therefore, this estimate may understate the possible load. The dioxin concentration in liquid soap is based on 1 sample. “Non-detects” were taken to equal zero; the detection limits ranged from 4 to 9 pg/l, depending on the congener. Of the 17 congeners for which TEFs exist, 9 were detected.

APPENDIX D

Dioxin Loads from
Human Waste and Food Waste

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LARRY WALKER ASSOCIATES

MEMORANDUM

DATE: August 18, 1997

TO: Kelly Moran, Palo Alto RWQCP

FROM: Betsy Elzufon and Ashli Cooper, LWA

SUBJECT: Dioxin Loads from Food and Human Wastes

Dioxins were identified as a pollutant of concern by the Palo Alto Regional Water Quality Control Plant (RWQCP) in the 1997 *Clean Bay Plan* because of dioxin levels measured in the RWQCP's sludge. Sources of dioxins to the RWQCP are under evaluation. As part of this effort, annual loads of dioxins to the RWQCP from food and human waste were estimated. Table 1 compares the estimated dioxin loads from food and human wastes to the estimated dioxin loading in the RWQCP influent.

Table 1. Dioxin Loads from Food and Human Waste

Total estimated dioxin load from food waste (10^{-8} lb TEQ/day)	0.71
Total estimated dioxin load from human waste (10^{-8} lb TEQ/day)	3.1
Total estimated dioxin load (10^{-8} lb TEQ/day)	3.8
Total estimated RWQCP influent load (10^{-8} lb TEQ/day)	9.5-156

Table 2 summarizes the calculations conducted to determine food and human waste dioxin loads. The load from food waste was estimated by multiplying the amount of food waste disposed of annually by the amount of dioxin in the food. Estimates of food waste disposed were taken from the *Residential Metals Study* (LWA, 1994). Most of the concentrations of dioxin in the food were obtained from *Levels of Dioxins, Dibenzofurans, PCB and DDE Congeners in Pooled Food Samples Collected in 1995 at Supermarkets Across the United States* (Schecter, et.al., 1997). Values for the population and number of households in the RWQCP's service area were taken from the draft *Projections '96: Forecasts for the San Francisco Bay Area to the Year 2015* (Association of Bay Area Governments, 1995). All estimates are presented in the EPA defined TEQ units for combined dioxins and furans.

Dioxin levels in food seem to be primarily related to the amount of animal fat in the food. High levels of dioxins were found in butter, cheese, eggs, beef and ice cream as compared to very low levels in fruits, vegetables, and grains. The highest concentrations of dioxin by far were found in fish, particularly shellfish. The quantity of food disposed to the sewer was not available for several of the food items for which dioxin concentrations were found. The most notable value missing is the disposal value for butter. Butter has the highest dioxin concentration found in foods other than fish. Estimates for the value of butter disposed to the sewer would provide a more accurate estimate of the dioxin load to the RWQCP from food waste.

Since dioxins are generally associated with animal fat content, very few studies have been done to determine the dioxin concentrations in fruits and vegetables. Most of the values for dioxin levels in fruits or vegetables found were reported for fruits or vegetables in general, not for specific fruits or vegetables. Therefore, the food waste dioxin load calculation was estimated for three categories: fruits; vegetables; and potatoes, cereals and grains. The amount disposed to the sewer was estimated by using the sum of available disposal amounts from the *Residential Metals Study* for specific foods in each category. The fruit disposal value is estimated as the sum of disposal values for apples, bananas, oranges, and strawberries listed in the *Residential Metals Study*. The sum of disposal values for asparagus, green beans, lettuce, peas, and celery is used to estimate the disposal value for green vegetables. The potato, cereal, and grains disposal quantity is estimated as the sum of potato and flour disposal values.

The values for the amount of food disposed to the sewer system were converted from the original units of amount disposed per household to amount disposed per person. The food disposal values originated from a survey of households in San Jose. Since there was no data available on the size of the households surveyed, the values were assumed to represent a range of household sizes and the data was not adjusted for the difference between household sizes in San Jose and Palo Alto. The values in Table 2 represent the disposal values per household divided by the average number of people per household in Palo Alto, 2.9.

The total load from human waste was estimated by multiplying the population in the RWQCP's service area by the amount excreted per person. Values for the amount of dioxin excreted by a typical person during a 24-hour period were taken from *Methodology for the Analysis of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Feces.* The total estimated dioxin load is the sum of the loads from human and food waste.

The estimates presented in Table 2 contain many uncertainties. The value for dioxin concentrations in human waste is an average of samples from five individuals. The uncertainty in the measurements was not determined, but the small sample size suggests high uncertainty for the load estimates. As described above, food disposal amounts are not available for several of the foods in which dioxin has been found. In addition to butter, food disposal values are also not available for pork, hot dogs/bologna and ice cream. Although the amount of dioxin that these foods would contribute to the load is uncertain, the missing values lead to an estimate of the dioxin load from food wastes that is probably low. These factors plus the uncertainty present from the food disposal values leads to a highly uncertain estimate for dioxin loads from food and human wastes.

Table 2: Food and Human Waste Dioxin Load Calculations

A. FOOD WASTE CALCULATION					
FOOD	Average quantity disposed to the sewer in 1 week in ounces per person[1]	Average per year per person (oz)	Population	Food Dioxin Conc. (pg TEQ/g food)[2]	Dioxin Loading (lb TEQ/day)
Beef	0.59	30.5	236200	0.25	3.04E-10
Chicken	0.86	44.8	236200	0.18	3.22E-10
Pork				0.21	
Hot Dog/Bologna				0.29	
Shellfish	0.14	7.2	236200	1.44 [3]	4.11E-10
Fresh Fish	0.14	7.2	236200	0.69	1.98E-10
Eggs	8.1	421	236200	0.31	5.21E-09
Butter				0.52	
Cheese	0.07	3.6	236200	0.27	3.86E-11
Milk	2	104	236200	0.1	4.15E-10
Ice Cream				0.24	
Fruit	1.4 [5]	73.5	236200	0.00082 [4]	2.41E-12
Green Vegetables	1.3 [5]	69.9	236200	0.062[4]	1.73E-10
Potato, Cereal, Grain	1.6[5]	82.5	236200	0.001 [4]	3.29E-12
Rice	0.86	44.8	236200	0.0004 [4]	7.16E-13
TOTAL FOOD WASTE LOAD (lb/day)					7.08E-09
B. HUMAN WASTE CALCULATION					
			Population	Excretion (pg/day/cap) [6]	
HUMAN WASTE LOAD (lb/day)			236200	60[7]	3.12E-08
TOTAL LOAD (Human and Food Waste) (lb/day)					3.83E-08

Notes:

(1) *Residential Metals Study*, LWA, 1994

(2) Values from *Levels of Dioxins, Dibenzofurans, PCB and DDE Congeners in Pooled Food Samples Collected in 1995 at Supermarkets Across the United States* (Schecter, 1997) unless otherwise stated.

(3) *Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans (PCDD/PCDF) in Food Samples Collected in Southern Mississippi, USA* (Fiedler, 1997)

(4) *Dietary Intake of Dioxin-Related Compounds through Food in Japan* (Takayama, 1991)

(5) Values for the amount of food disposed calculated as the sum of the individual foods in each category (i.e. fruit disposal is the sum of the apple, banana, orange, and strawberry disposal amounts, and green vegetables is the sum of asparagus, green beans, lettuce, peas, and celery disposal amounts).

(6) *Methodology for the Analysis of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Feces* (Wendling, 1990)

(7) Since the TEQ units used were not described in the text of the article, it was assumed that the TEQ units were the same as the others used in this estimate.

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FAX COVER SHEET

LARRY WALKER ASSOCIATES

Date: September 24, 1997

To: Kelly Moran

Fax No: (650) 494-3531

From: Ashli Cooper, LWA

Number of Pages to Follow: 0

Remarks:

Kelly,

The following table summarizes how the dioxin and PCB articles handle non-detect data and the number of samples taken to obtain the concentrations.

Article	Non-detect data	No. of Samples
Fiedler, H., et. al.: *PCDD/PCDF in Food Samples Collected in Southern Mississippi, USA.*	One-half of the detection limit used.	2-3 for each food type; 43 total
Schecter, A., et. al.: *Levels of Dioxins, Dibenzofurans, PCB and DDE Congeners in Pooled Food Samples Collected in 1995 at Supermarkets Across the United States.*	One-half of the detection limit used.	12 pooled* samples, 1 for each type of food
Takayama, K., et. al.: *Dietary Intake of Dioxin-Related Compounds through Food in Japan.*	Non-detects = 0	Unknown (samples taken during three years)
Mes, J., et. al.: *Levels of specific PCB congeners in fatty foods from five Canadian cities between 1986 and 1988.*	Non-detects = 0 ? (Not really clear)	155 composite samples
Yoshida, S., et. al.: *Levels of Pesticide Residues and PCB in Diet by Model Menu Study during a One-week Period*	Unknown	Unknown
Abraham, K., et. al: *Intake and Fecal Excretion of PCDDs, PCDFs, HCB and PCBs (138, 153, 180) in a Breast-fed and a Formula-fed Infant.*	One-half of the detection limit used.	2 for 5-month-old breast-fed infant.

* The samples analyzed represented a mixture of similar foods from supermarkets around the country. For example, the butter sample was made up of unsalted butter from San Diego combined with salted sweet cream butter from Atlanta.

CITED REFERENCES

Association of Bay Area Governments (ABAG). *Projections '96: Forecasts for the San Francisco Bay Area to the Year 2015.* December, 1995.

Fiedler, H.; Cooper, K.R.; Bergek, S.; Hjelt, M.; Rappe, C. *Polychlorinated Dibenzo-p-dioxins and Polychlorinated Dibenzofurans (PCDD/PCDF) in Food Samples Collected in Southern Mississippi, USA.* Chemosphere 1997 34(5) 1411-1419.

Schecter, A.; Cramer, P.; Boggess, K.; Stanley, J.; Olson, J.R. *Levels of Dioxins, Dibenzofurans, PCB and DDE Congeners in Pooled Food Samples Collected in 1995 at Supermarkets Across the United States.* Chemosphere 1997 34(5) 1437-1447

Takayama,K; Miyata, H.; Aozasa, O.; Mimura, M.; Kashimoto, T. *Dietary Intake of Dioxin-Related Compounds Through Food in Japan.* Journal of the Food Hygienic Society of Japan, 1992 32(6):525-532.

Wendling, J.M.; Orth, R.G.; Poiger, H.; Hileman, F.D. *Methodology for the Analysis of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Feces.* Chemosphere, 1990 20(3/4) 343-347.

ADDITIONAL REFERENCES

Lovett, A.A.; Foxall, C.D.; Creaser, C.S.; Chewe, D. *PCB and PCDD/DF Congeners in Locally Grown Fruit and Vegetable Samples in Wales and England.* Chemosphere 1997 34(5) 1421-1436.

Pluim, H.J.; Wever, J; Koppe, J.G.; Slikke, J.W.; Olie, K. *Intake and Faecal Excretion of Chlorinated Dioxins and Dibenzofurans in Breast-Fed Infants at Different Ages.* Chemosphere, 1993 26(11):1947-1952.

Schecter, A.; Li, L. *Dioxins, Dibenzofurans, Dioxin-like PCBs, and DDE in U.S. fast food, 1995.* Chemosphere, 1997 34(5-7):1449-1457.

Steering Group on Chemical Aspects of Food Surveillance. *Great Britain Ministry of Agriculture Fisheries and Food Surveillance Paper No. 31. Dioxins in Food. (UK).* 1992.

Theelen, R.M.C.; Liem, A.K.D; Slob,W.; Van Wijnen, J.H. *Intake of 2,3,7,8 Chlorine Substituted Dioxins, Furans, and Planar PCBs from Food in the Netherlands: Median and Distribution. (1987-1988).* Chemosphere, 1993 27(9):1625-1635.

Travis, C.C.; Hattemer-Frey, H.A.; Silbergeld, E. *Dioxin, Dioxin Everywhere.* Environmental Science & Technology, 1989 23 (9):1061-1063.

APPENDIX E

Dioxins Bibliography

Dioxins Bibliography

Abraham, K., A. Hille, M. Ende, and H. Helge. 1994. Intake and Fecal Excretion of PCDDs, PCDFs, HCB and PCBs (138, 153, 180) in a Breast-Fed and Formula-Fed Infant. *Chemosphere*, 29 (9-11): 2279-2286.

Alcock, R.E. and K.C. Jones. 1996. Dioxins in the Environment: A Review of Trend Data. *Environmental Science and Technology*, 30 (11): 3133-3143.

Bateman, B. and B. Deboisblanc. 1996. *Air Emissions of Dioxins in the Bay Area*. Bay Area Air Quality Management District, Toxic Evaluation Section. March 27.

Beck, H., K. Eckart, W. Mathar, and R. Wittkowski. 1988. Occurrence of PCDD and PCDF in Different Kinds of Paper. *Chemosphere*, 17 (1): 51-57.

Brzuzy, Louis P. and Ronald A. Hites. 1996. Global Mass Balance for Polychlorinated Dibenzo-p-dioxins and Dibenzofurans. *Environmental Science and Technology*, 30 (6): 1797-1804.

California Bay Area Air Quality Management District. 1996. *Air Emisions of Dioxins in the Bay Area*. Prepared by the Staff of the Toxic Evaluation Section.

California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. 1997. Draft for Public Comment, *Air Toxics Hot Spots Program Risk Assessment Guidelines: Technical Support Document for Determining Cancer Potency Factors*. April.

California Regional Water Quality Control Board, San Francisco Bay Region. 1997. *Survey of Storm Water Runoff for Dioxins in the San Francisco Bay Area*. February.

Duarte-Davidson, R., A. Sewart, R.E.Alcock, I.T. Cousins, and K.C. Jones. 1997. Exploring the Balance between Sources, Deposition, and the Environmental Burden of PCDD/Fs in the U.K. Terrestrial Environment: An Aid to Identifying Uncertainties and Research Needs. *Environmental Science and Technology*, 31 (1): 1-11.

Eduljee, G.H., P. Dyke, and P.W. Cains. 1995. PCDD/PCDF Releases from Various Waste Management Strategies. *Warner Bulletin* No. 46, August.

Eduljee, G.H., P. Dyke, and P.W. Cains. 1997. The Effect of Changing Waste Management Practices on PCDD/PCDF Releases from Household Waste Recycling and Disposal Practices. *Chemosphere*, 34 (5-7): 1615-1622.

Fiedler, H. and O. Hutzinger. 1992. Sources and Sinks of Dioxins: Germany. *Chemosphere*, 25 (7-10): 1487-1491.

Fiedler, Heldelor. 1993. Formation and Sources of PCDD/PCDF. *Organohalogen Compounds*, 2: 221-228.

Gihr, R., W. Klopffer, G. Rippen, and H. Partscht. 1991. Investigations on Potential Sources of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Sewage Sludge. *Chemosphere*, 23 (11-12): 1653-1659.

Heindl, A., and O. Hutzinger. 1986. Search for Industrial Sources of PCDD/PCDFs: II. Metal Chlorides. *Chemosphere*, 15 (5): 653-658.

Horstmann, M., A. Kaune, M.S. McLachlan, M. Reissinger, and O. Hutzinger. 1992. Temporal Variability of PCDD/F Concentrations in Sewage Sludge. *Chemosphere*, 25 (7-10): 1463-1468.

Horstmann, M., M.S. McLachlan, M. Reissinger. 1993. Investigations of the Origin of PCDD/F in Municipal Sewage Sludge. *Chemosphere*, 27 (1-3): 113-120.

Horstmann, Michael and Michael S. Mclachlan. 1995. Concentrations of Polychlorinated Dibenzo-p-Dioxins (PCDD) and Dibenzofurans (PCDF) in Urban Runoff and Household Waters. *Chemosphere,* 31 (3): 2887-2896.

Horstmann, Michael and Michael S. McLachlan. 1995. Results of an Initial Survey of Polychlorinated Dibenzo-p-Dioxins (PCDD) and Dibenzofurans (PCDF) in Textiles. *Chemosphere*, 31 (2): 2579-2589.

Horstmann, Michael, and Michael S. McLachlan. 1994. Textiles as a Source of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD/F) in Human Skin and Sewage Sludge. *Environ. Sci. & Pollut. Res.* 1 (1) 15-20.

Keeler, G.J., J.M. Pacyna, T.F. Bidleman, and J.O. Nriagu. 1993. *Identification of Sources Contributing to the Contamination of the Great Waters (Revised).* Sponsored by U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA/453/R-94/087. March 17.

Kjeller, Lars-Owe and Christopher Rappe. 1995. Time Trends in Levels, Patterns and Profiles for Polychlorinated Dibenzo-p-dioxins, Dibenzofurans, and Biphenyls in a Sediment Core from the Baltic Proper. *Environmental Science and Technology,* 29 (2): 346-355.

Klopffer, Walter. 1996. Environmental Hazard Assessment of Chemicals and Products. Part V. Anthropogenic Chemicals in Sewage Sludge. Pollutants of Concern: 1067-1080.

LeBel, G., D. Williams, and F. Benoit. 1992. Chlorinated Dibenzodioxins and Dibenzofurans in Consumer Paper Products. *Chemosphere*, 25 (11): 1683-1690.

Lester, Stephen, and Charlotte Brody. 1997. How to Start to Stop Dioxin Exposure in Your Community. Citizens Clearinghouse for Hazardous Waste. (http://www.envirolink.org/issues/dioxin/dioxin.html)

Lexen, K., C. Wit, B. Jansson, L. Kjeller, S. Kulp, K. Ljung, G. Soderstrom, and C. Rappe. 1993. Polychlorinated Dibenzo-p-dioxin and Dibenzofuran Levels and Patterns in Samples from Different Swedish Industries Analyzed with the Swedish Dioxin Survey. *Chemosphere*, 27 (1-3): 163-170.

Lovett, A. A. 1997. PCB and PCDD/DF Congeners in Locally Grown Fruit and Vegetable Samples in Wales and England. *Chemosphere*, 34 (5): 1421-1436.

McLachlan, Michael S., Michael Horstmann, Margit Hinkel. 1996. Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans in Sewage Sludge: Sources and Fate Following Sludge Application to Land. *The Science of the Total Environment*, 185: 109-123.

Naf, C., D. Broman, R. Isha and Y. Zebuhr. 1990. PCDDs and PCDFs in Water, Sludge and Air Samples From Various Levels in a Waste Water Treatment Plant with Respect to Composition Changes and Total Flux. Chemosphere, 20 (1-2): 1503-1510.

Pluim, H. J., J. Wever, J. G. Koppe, J. W. Slikke, and K. Olie. Intake of Fecal Excretion of chlorinated dioxins and Dibenzofurans in Breast-Fed Infancts at Different Ages. *Chemosphere*, 26 (11): 1947-1952.

Poiger, H. and C. Schlatter. 1986. Parmacokinetics of 2,3,7,8-TCDD in Man. *Chemosphere*, 15 (9-12): 1489-1494.

Rappe, C. and R. Andersson. 1992. Levels of PCDDs and PCDFs in Human Feces. *Organohalogen Compounds*, 9: 195-198.

Rappe, C., R. Andersson, K. Lundstrom, and K. Wiberg. 1990. Levels of Polychlorinated Dioxins and Dibenzofurans in Commercial Detergents and Related Products. *Chemosphere*, 21 (1-2): 43-50.

Rappe, Christoffer; Lars-Owe Kjeller, and Rolf Andersson. 1989. Analyses of PCDDs and PCDFs in Sludge and Water Samples. *Chemosphere*, 19 (1-6): 13-20.

Remmers, J., A. Dupuy, D. McDaniel, R. Harless, and D. Steele. 1992. Polychlorinated Dibenzo-p-Dioxin and Dibenzofruran [sic] Contamination in Chloranail [sic] and Carbazole Violet. *Chemosphere*, 25 (7-10): 1505-1508.

Rieger, R., and K. Ballschmiter. 1992. Search for Sources of CLxDD/CLxDF in Sewage Sludge of Mixed Industrial/Domestic Origin. *Organohalogen Compounds*, 9: 203-206.

Schecter, A. 1994. *Dioxins and Health*. New York: Plenum Press.

Schecter, Arnold, Paul Cramer, Kathy Boggess, John Stanley, James R. Olson. Levels of Dioxins, Dibenzofurans, PCB and DDE Congeners in Pooled Food Samples Collected in 1995 at Supermarkets Across the United States. 1997. *Chemosphere*, 34 (5-7): 1437-1447.

Schrey, Petra, Jurgen Wittsiepe, Petra Mackrodt, Fidelis Selenka. 1996. Human fecal PCDD/F-Excretion Exceeds the Dietary Intake. 8 pp. (http://www.hygiene.ruhr-uni-bochum.de...n/www-public/adults-excretion/Index.html).

Shroeter, H.O. 1997. Toxic Contaminant Loadings from Municipal Sources in Ontario Areas of Concern. *Water Quality Research*, 32 (1): 7-22.

Steering Group on Chemial Aspects of Food Surveillance. 1992. *Great Britain Ministry of Agriculture Fisheries and Food Surveillance Paper No. 31. Dioxins in Food.* (UK).

Stewart, A., S.J. Harrad, M.S. McLachlan, S. P. McGrath, and K.C. Jones. 1995. PCDD/Fs and Non-o-PCBs in Digested U.K. Sewage Sludges. *Chemosphere*, 30 (1): 51-57.

Theelen, R. M. C., A. D. D. Liem, W. Slob, and J. H. Van Wijnen. 1993. Intake of 2,3,7,8-Chlorine substituted dioxins, furands, and Planar PCBs from Food in the Netherlands: Median and Distribution. (1987-1988). C*hemosphere*, 27 (9): 1625-1635.

Towara, J., B. Hiller, O. Hutzinger. 1992. PCDD/F in Distillation Residues from Dry Cleaners. *Chemosphere* 25 (7-10): 1509-1516.

Travis, C. C., H. A. Hattemer-Frey, and E. Silbergeld. 1989. Dioxin, Dioxin Everywhere. *Environmental Science & Technology*, 23 (9): 1061-1063.

U.S. Environmental Protection Agency (EPA). 1994. Estimating Exposure to Dioxin-like Compounds (Review Draft), EPA/600/6-88/005/Ca. June.

U.S. Environmental Protection Agency (EPA). 1994. *Health Assessment Document for 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds*, Vol. III (Review Draft), EPA/600/BP-92-001c. August.

Van Emden, H.F., and D.B. Peakall. 1996. *Beyond Silent Spring: Integrated Pest Management and Chemical Safety*. United Nations Environment Program. New York: Chapman & Hall.

Wendling, J.M., R.G. Orth, H. Poiger, F.D. Hileman. 1990. Methodology for the Analysis of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin in Feces. *Chemosphere*, 20 (3/4): 343-347.

Wilken, Michael; Frank Neugebauer, Barbara Zeschmar-Lahl, Johannes Jager. 1990. PCDD/PCDF Balance of Different Municipal Waste Management Methods, III: Composting. *Organohalogen Compounds*, 4: 335-338.

Wittsiepe, J., U. Ewers, P. Schrey, and F. Selenka. 1997. PCDD/F in House Dust. (http://www.hygiene.ruhr-uni-bochum.de).