

POLYCHLORINATED BIPHENYLS

(PCBs)

SOURCE IDENTIFICATION



October 28, 1997

Prepared for
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SUMMARY

The Palo Alto Regional Water Quality Control Plant (RWQCP) conducted this study to investigate sources of polychlorinated biphenyls (PCBs) in the plant's influent. The goals of this study are to identify and quantify, to the extent possible, sources of PCBs in the RWQCP influent; to identify areas where more data and analysis are needed; and to identify sources that may offer opportunities for future pollution prevention efforts. The primary conveyances through which PCBs arrive at the RWQCP appear to be storm water inflow, landfills, hazardous waste management, human waste, and food waste. The original sources of these PCBs are primarily PCB-containing materials and equipment manufactured prior to 1977, when the manufacture of PCBs ceased (PCB manufacturing was banned in the U.S. in 1979). Some PCBs may also travel to the RWQCP service area from outside the U.S. through environmental transport mechanisms. Substantial uncertainties exist in the estimated PCB loads to the RWQCP; therefore, significant sources or conveyances of PCBs may remain unidentified. Further study should involve testing the RWQCP influent, analyzing additional samples of identified PCB discharges, and investigating the extent of continuing use and handling of PCB-containing equipment. In part, future source reduction strategies may need to focus on sources that the RWQCP does not directly control, such as atmospheric deposition.

BACKGROUND

Chemical Characteristics and Toxicity

PCBs are a group of synthetic chemicals manufactured by adding chlorine to biphenyl. As shown on Figure 1, a biphenyl molecule has 10 locations where chlorine atoms may attach. By varying the number and location of the chlorine atoms, a total of 209 unique PCB molecules, or congeners, can be created. Less chlorinated congeners are oily liquids, while more chlorinated PCBs are viscous and resinous (EPA, 1980).

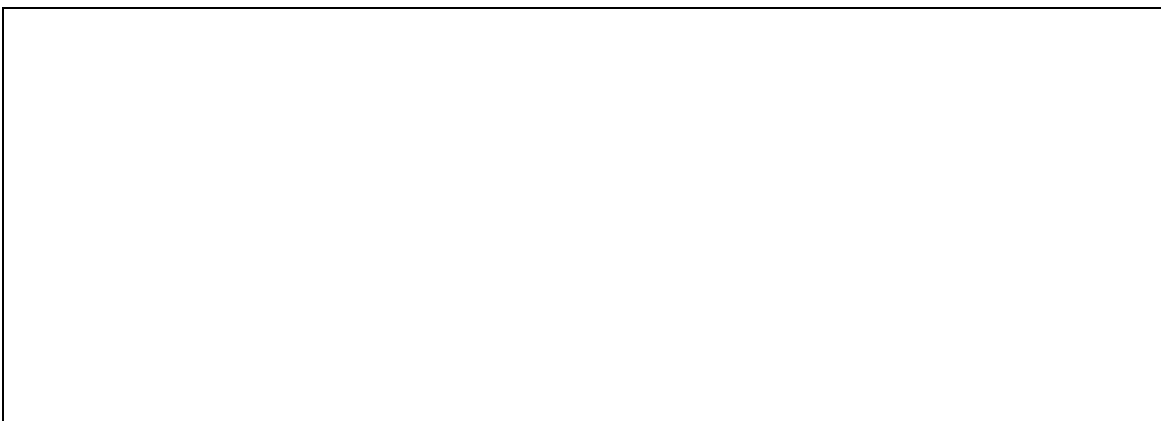
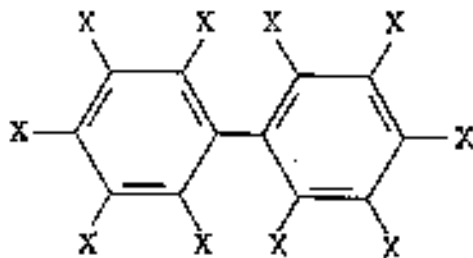


FIGURE 1: Chemical Structure of PCBs



X = H or Cl

PCBs are very stable and do not readily undergo chemical reactions (EPA, 1980). PCBs do not burn easily, have a high heat capacity, and do not explode. For these reasons, they were widely used as coolants, insulating materials, and lubricants in electrical equipment, such as transformers and capacitors (EPA, 1980). They have also been used in plastics to increase flexibility and durability without adding to fire hazards. Congeners with 5 or fewer chlorine atoms biodegrade very slowly, and those with more chlorine atoms undergo “practically negligible” biodegradation (EPA, 1987). Because PCBs are very nonpolar molecules, they are lipophilic; they adhere to organic matter, such as fats, and are not very soluble in water. As a result, PCBs have extremely high rates of bioaccumulation, particularly in fish and other aquatic organisms.

In general, PCBs become more toxic with increasing chlorine content (Tanabe, 1988). Toxic effects of PCBs in humans include chloracne, pigmentation of skin and nails, excessive eye discharge, swelling of eyelids, distinctive hair follicles, and gastrointestinal disturbances. PCBs are also listed as carcinogens by the U.S. Environmental Protection Agency (EPA). PCBs can reduce the ability of animals to reproduce and can cause other toxic symptoms, such as carcinoma, liver ailments, adenofibrosis, weight and hair loss, mouth and eyelid edema, acneform lesions, decreased hemoglobin, and gastric ulcers (Windholz, 1983). Eleven of the 209 congeners are capable of adopting a co-planar geometry similar to polychlorinated dibenzo-*p*-dioxins and dibenzofurans. Because of the similar size and shape of these co-planar PCBs when compared to these other substances, some PCBs are believed to exhibit dioxin-like toxicity (Baird, 1995).

History of Use

PCBs were reportedly formulated as early as 1881, but they were not commercially produced until 1929. Monsanto was the only U.S. manufacturer of PCBs, producing them under the trade name Aroclor. Until 1957, PCBs were used almost exclusively in electrical transformers and capacitors. After 1957, PCBs were still used primarily for transformers and capacitors, but numerous other applications became widespread, such as hydraulic fluids, lubricants, plasticizers, wood preservatives, paints, and sealants (EPA, 1987).

In 1966, a Swedish scientist studying wildlife found PCBs in many animals and prepared the first report of PCBs in the environment. His findings provoked a subsequent flurry of research, which found PCBs to be widespread (van Emden and Peakall, 1996). As a result of these findings, Monsanto voluntarily restricted the sale of PCBs in 1971 to “closed system” products with limited potential for release. Consequently, 1970 was the peak year for PCB production. In 1977, Monsanto ended its manufacture of PCBs due to the increased concerns about their environmental impacts and the availability of replacement products (EPA, 1987).

In 1979, the EPA banned the manufacture and import of PCBs to the U.S., as well as their processing or use, except in a totally enclosed manner (such as in transformers). Subsequently, EPA authorized uses that were not totally enclosed, including servicing

transformers; use in and servicing railroad transformers; and use in heat transfer systems, hydraulic systems, carbonless copy paper, pigments, electromagnets, natural gas pipeline compressors, research and development, and microscope mounting media (EPA, 1987).

Up to 1977, an estimated 640,000 metric tons of PCBs were produced in the U.S. (Keeler et al., 1993), representing approximately half of worldwide production (EPA, 1980). About 450,000 pounds of PCBs were also imported, primarily for use in non-closed systems. Imports apparently increased after Monsanto restricted its PCB production until the ban became effective in 1979 (EPA, 1987). Table 1 shows a breakdown of the primary uses of PCBs, and Table 2 shows a detailed list of known historic PCB uses. Appendix A provides typical PCB concentrations for several PCB-containing products. Table 3 shows the status, as of 1982, of the PCBs produced in the U.S. (Keeler et al., 1993). Because much of the PCBs produced were either still in service or circulating in the environment at that time, a substantial portion of the total PCB production is probably still a potential source of environmental release today (Keeler et al., 1993).

Environmental Transport

Although PCBs are not particularly volatile, because of their stability and persistence in the environment, they can exchange freely between environmental media, including air, water, soil, vegetation, and animals. PCBs can travel long distances by wind and deposit on soil and water. By cycling continuously through the environment, PCBs are found worldwide in soil, fresh water, sediments, and oceans, particularly in industrialized areas of the northern hemisphere. They have been found in air, plants, and water as far away as the Arctic and Antarctic (Tanabe, 1988).

TABLE 1: Primary Uses of PCBs

Use	Percent of Total Production (%)	Quantity (10⁶ pounds)
Closed system electrical and heat transfer fluids (transformers, capacitors, fluorescent light ballasts)	60	850
Plasticizers (additives in plastics that maintain softness and pliability)	25	350
Hydraulic fluids and lubricants	10	140
Miscellaneous use (flame retardants, paints, inks, sealants, and carbonless copy paper)	5	71
TOTAL	100	1,400

Source: Keeler et al., 1993

TABLE 2: Specific Uses of PCBs

Use	Examples
Electrical Applications	Transformers and capacitors for electric utilities Fluorescent light ballasts Televisions Appliances with PCB capacitors (e.g., refrigerators, washing machines, air conditioners) Aircraft engines Large motors at industrial plants Small capacitors, pumps, and fans Vacuum pumps Electromagnets Railroad transformers Circuit breakers Voltage regulators Natural gas pipeline compressors Mining equipment
Hydraulic Fluids	Hydraulic fluids in lifts, hoists, heavy machinery, brakes, miscellaneous equipment Hydraulic dye casting machinery
Plasticizers	Polyvinyl chloride (PVC) plastic Laminating adhesives (involving polyurethanes and polycarbonates to prepare safety and acoustical glasses) Plastic decorative articles
Miscellaneous Uses	Paints Wood preservatives Sealants and caulking Varnish Adhesives Microscope oil Waterproofing Flame proofing Carbonless copy paper Wax extenders (used by casting industry for molds) Pesticide extenders Cutting oils De-inking solvents for recycling newsprint Textiles (for ironing board covers, yarns and polypropylene and sealing)

formulations for waterproof canvas)

TABLE 2: Specific Uses of PCBs (continued)

Use	Examples
Miscellaneous Uses (continued)	Film casting solutions for electrical coatings, insulating tape, and protective lacquer Additives to epoxy resins (resins used as protective coatings on metals) Colored copying paper (paper was then often recycled into other paper items, including food packaging); graphic duplicating processes, xerographic transfer processes and solvent-free printing Toilet paper (PCB contamination resulted from the use of recycled paper) Soil erosion retardant Insecticide and bactericide additives Printing inks Pigments Mineral oil cable Microscopy mounting mediums

Source: EIP Associates

TABLE 3: Status of PCBs in the U.S. as of 1982

Status	Percent of Total Produced (%)	Quantity (10 ⁶ pounds)
Destroyed	3	42
Exported	11	160
Buried in landfills	21	300
Still in Service	54	760
Circulating in the Environment	11	160
TOTAL	100	1,400

Source: Keeler et al., 1993

In 1985, an estimated 900,000 kilograms (kg) of PCBs cycled through the atmosphere over the U.S. About 18,000 kg of PCBs were in the air at any given time. At this concentration, the annual deposition from atmospheric concentrations was estimated to be about 60 grams per square kilometer per year [g/(km²/year)] (Murphy et al., 1985). Several studies indicate that PCB air concentrations declined steadily after the ban of their manufacture; however, since the early to mid-1980s, there does not appear to be a

significant decline in air concentrations (Gobas et al., 1995; Jones et al., 1995). The Bay Area Air Quality Management District has not attempted to inventory PCB air emissions in the San Francisco Bay Area (Bateman, 1997).

PCBs can evaporate from water to air, but because PCBs are only slightly soluble in water, they adhere strongly to any soil or sediments present. This reduces the ability of PCBs in water to evaporate to the air. Instead, PCBs build up in sediments, where their concentrations can exceed those in the surrounding water by orders of magnitude. Because PCBs are lipophilic, PCBs in water and sediments bioaccumulate in fish and marine life. PCBs also bioaccumulate in plants, birds, terrestrial animals, agricultural livestock, and domestic animals. PCB concentrations increase by orders of magnitude as they rise through the food web, particularly as they reach higher organisms. In this way, a major route of human exposure to PCBs is through food.

SOURCE IDENTIFICATION

Purpose of Study

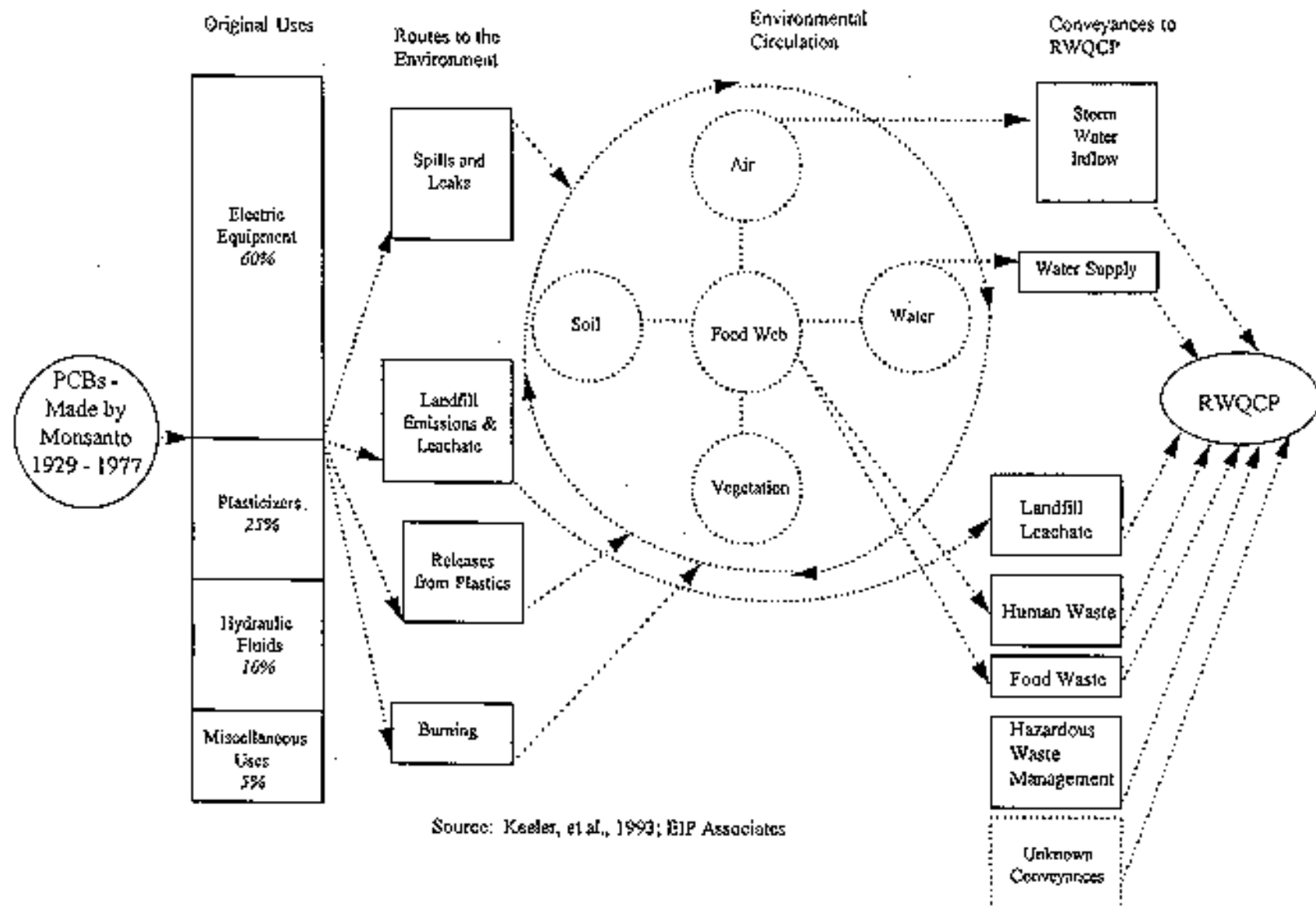
Each day, the RWQCP releases about 6×10^{-5} pounds of PCBs to the environment through its treated effluent and could potentially release PCBs to soil if sludge management practices were to change. RWQCP releases are of concern because of the human and environmental toxicity of PCBs and their environmental persistence. For this reason, the RWQCP has embarked on this study to explore sources of PCB discharges to the sewer contributing to the plant's influent loading. The goal of this effort is to identify sources of PCBs in the RWQCP influent, estimate their relative importance, identify areas where more information is needed, and provide information useful in exploring possible opportunities for pollution prevention.

Results of Study

Because of the persistence of PCBs 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, PCBs have been found far away from human populations (Erickson, 1997). For this reason, some PCBs in the RWQCP service area are probably released from sources that are far away, many of which may be outside the U.S. PCBs may also be released from local sources. PCBs exist in some materials and equipment that predate the sales ban. While individuals and businesses that handle PCB-containing items would not normally release PCBs to the environment, unintentional releases do occur. PCBs released to the environment are picked up and passed through the environment via one or more "conveyances," the last of which discharge the PCBs to the RWQCP. The intermediate conveyances are primarily atmospheric deposition and the food web.

Figure 2 illustrates how PCBs, manufactured in the U.S. by Monsanto until 1977, could travel to the RWQCP through storm water inflow, the water supply, landfill leachate, human waste, food waste, and hazardous waste management. These conveyances are

FIGURE 2: Sources of PCBs to the RWQCP



Source: Keeler, et al., 1993; EIP Associates

discussed below. Other routes may convey PCBs to the RWQCP, but insufficient information is available regarding them to provide a meaningful analysis. Table 4 presents the estimated load for each of the identified conveyances and indicates whether it is likely to contribute substantially to the overall RWQCP influent load. Table 5 reiterates the relatively large conveyances and summarizes the primary sources contributing to them.

Storm Water Inflow

PCBs that are in the air or on exposed surfaces may be picked up by rain water and carried into storm water runoff. In the RWQCP service area, most storm water runoff flows directly to the San Francisco Bay. Some storm water runoff enters manholes and other openings in the sewer system; this water is called “inflow.” Sources of PCBs in storm water may include leaks and spills from transformers and capacitors used by utilities and private industries (see Appendix B); leaks of PCB-containing hydraulic fluids from equipment; improper disposal of PCB-containing hydraulic fluids; or leaching from items coated with PCB-containing paints, sealants, wood preservatives, or other materials. Atmospheric deposition from national and international PCB emissions could contribute substantially to PCB levels in storm water.

Recent data for concentrations of PCBs in storm water in the RWQCP service area are unavailable. However, as discussed in Appendix C, a study from the Santa Clara Valley Urban Runoff Program (which covers a large geographic area that includes most of the RWQCP service area) provides a basis for estimating the maximum PCB concentrations and total loadings in storm water flowing into the RWQCP.

TABLE 4: Estimated PCB Loads Conveyed to the RWQCP

Conveyance to RWQCP	Estimated Load (10⁻⁵ pounds/day)	Uncertainty of Data	Contribution to RWQCP Load*
Water Supply	< 9,000	Very High	possibly LARGE
Storm Water Inflow	< 700	Very High	possibly LARGE
Landfills	10	Very High	LARGE
Hazardous Waste Management	10	Very High	LARGE
Human Waste	4	Very High	possibly LARGE
Food Waste	2	Very High	possibly LARGE
Other Conveyances	NA	NA	Unknown

NA = Not Available

* The RWQCP generally defines sources equal to or greater than 10% of its influent pollutant load as large. However, PCB concentrations in RWQCP influent are unavailable. For purposes of this report, a relatively large contribution to the RWQCP influent is defined as a load on the order of magnitude of the effluent load, which is about 6 x10⁻⁵ pounds/day.

TABLE 5: Large PCB Conveyances and their Primary Sources

Large Conveyances to RWQCP	Most Important Sources
Water Supply	<ul style="list-style-type: none">• Air deposition of PCBs circulating in environment
Storm Water Inflow	<ul style="list-style-type: none">• Releases from sealants, paints, plastics• Air deposition of PCBs circulating in environment• Leaks and spills by utilities and private industries• Improper disposal of hydraulic fluids or other old equipment with PCBs
Landfills	<ul style="list-style-type: none">• Historic disposal practices
Hazardous Waste Management	<ul style="list-style-type: none">• Unknown
Human Waste	<ul style="list-style-type: none">• PCBs in food web• PCBs in air emissions (e.g., from sealants, paints, spills, landfills)
Food Waste	<ul style="list-style-type: none">• PCBs in food web

Human Waste and Food Waste

PCBs released to the environment can be trapped in the food web where they bioaccumulate in living things. In this way, PCBs can enter the RWQCP through food wastes and human wastes. Appendix D discusses PCB loads from these wastes (LWA, 1997).

Landfills

Leachate from two landfills in the service area (one in Palo Alto and one in Mountain View) is collected and discharged directly to the RWQCP. Leachate is composed of rain water that infiltrates the landfills, liquids contained in the waste deposited in the landfills, decomposed matter from the waste, and various contaminants collected by the water as it passes through the landfill.

Waste decomposition in the landfill generates gases that pass through the landfill as they rise to the surface (where they are typically collected). Gas collected from the Palo Alto

landfill powers a cogeneration facility that discharges liquid condensed from the landfill gases to the RWQCP.

Wastes containing PCBs were probably disposed of in the landfills, particularly at a time when PCB use was more prevalent and waste disposal restrictions were less rigorous than they are today. PCBs in landfills may eventually reach the environment through landfill gas emissions, landfill leakage, or leachate collection. Appendix C contains estimates of the contribution of these landfills to the influent PCB load at the RWQCP.

Hazardous Waste Management

Typically, if PCB-containing equipment is taken out of service, PCB waste (defined in California as containing 5 parts per million or greater PCBs) is shipped to a special hazardous waste management facility capable of handling PCBs. No such facilities exist in the RWQCP service area. One hazardous waste treatment and storage facility is located within the RWQCP service area. The source of PCBs in its discharge is unknown. The analysis presented here reports one grab sample analyzed using special techniques that provide exceptionally low detection limits.

Water Supply

Most water provided to the RWQCP service area comes from San Francisco's Hetch Hetchy system. Some water is provided by the Santa Clara Valley Water District from its Rinconada reservoir, and some water comes from local groundwater sources. Few data are available regarding possible PCB levels in the water supply (Cafkey, 1997; Scott, 1997); however, the Santa Clara Valley Water District has reported an upper limit for the PCB concentration in its water.

Although atmospheric deposition probably contaminates surface water reservoirs with some PCBs, levels of PCBs in the water supply are likely to be very low, particularly in light of the tendency of PCBs to bind to sediments and the relatively good protection of the watersheds serving the area from other sources of PCB contamination. Dilute levels of PCBs in the water supply could constitute a substantial load to the RWQCP as a result of the high volume of water provided. Nevertheless, the contribution of the water supply to the overall PCB load cannot be considered large with certainty.

Other Possible Conveyances to the RWQCP

This study may not have identified all possible conveyances of PCBs to the RWQCP. Other conveyances may exist. For example, a significant percentage of PCB releases in the RWQCP service area could result from incidental, unpredictable events. Since PCBs were used widely and continue to exist in many industrial, commercial, and residential contexts, their release undoubtedly occurs in situations where workers or residents would

not necessarily anticipate them. The following two incidents provide examples of what may be numerous incidental releases.

- In 1996, a contractor for the City of Palo Alto accidentally broke a gas main in downtown Palo Alto. An oil trap in the break contained PCBs due to the former owner's (Pacific Gas & Electric's) practice of lubricating compressors with PCB-laden oils. Some of those oils had been transported into the gas line system. Although Pacific Gas & Electric believed it had cleared out all oil traps with PCBs, the one that broke had a concentration of 49 parts per billion (ppb), just under the federal regulatory limit (see Appendix B). In that case, two vehicles and the side of a building were cleaned with high pressure hot water, which was then vacuumed and sent to a hazardous waste disposal facility. Sidewalk asphalt was also removed to a depth of about one inch (Centola, 1997).
- In another incident outside of the RWQCP service area, the East Bay Municipal Utility District was rehabilitating a reservoir and replaced some old gaskets and seals that workers did not realize at the time contained PCBs. PCBs were later found in the soils around the reservoir, and may have entered the water supply (Centola, 1997).

Another potential route through which PCBs could arrive at the RWQCP could be infiltration of the sewer system where it passes contaminated properties. No known uncontrolled PCB-contaminated properties have been identified in the RWQCP service area (Maez, 1997). If any such sites were to exist, PCBs could be slowly leaked to the RWQCP through infiltration and inflow from such sites.

UNCERTAINTIES

The total PCB influent load is unknown. The RWQCP has only measured PCB concentrations in the plant's effluent. Detecting PCBs in the effluent requires special analytical methods to obtain sufficiently low detection limits to quantify PCB levels. On the basis of limited data, the effluent loading is estimated to be about 6×10^{-5} pounds per day (lb/day). Because the RWQCP's ability to remove sludge from the wastewater treatment process is relatively good, the estimated effluent load is believed to represent between 1% and 10% of the potential influent load. Contaminant removal rates of this magnitude have been measured at other wastewater treatment plants with tertiary treatment processes (Morris and Lester, 1994; EPA, 1977).

Each estimated PCB load shown in Table 4 is evaluated according to the uncertainty of the data. Because all of these estimates are subject to substantial uncertainty, they are categorized as exhibiting "very high uncertainty." "Very high uncertainty" means calculations are based on interpretations of poorly documented sources and numerous important, yet uncertain, assumptions. The treatment of "non-detect" data may dominate the uncertainty. The errors could be more than one order of magnitude.

Because of the uncertainty of the results summarized in Table 4, they could be subject to over-interpretation. By categorizing each PCB conveyance to the RWQCP as large (as opposed to small), this report avoids inappropriately comparing the individual results with one another. Each estimate provided in Table 4 is subject to sufficient uncertainty that the estimates should *not* be added together to estimate the total of the known PCB loads. In fact, the estimated PCB loads listed in Table 4 may sum to a value substantially greater than the actual PCB load at the plant. Alternatively, Table 4 could fail to account for a substantial portion of the PCB load. Because the total PCB load in the RWQCP influent has not been determined, the amount of PCBs flowing to the RWQCP through unidentified routes cannot be estimated.

RECOMMENDATIONS

On the basis of the results presented in this report, RWQCP may wish to pursue (or encourage other more appropriate agencies to pursue) some of the following suggestions for further study:

- Test influent concentrations of PCBs.
- Test storm water runoff for concentrations of PCBs.
- Investigate likely use and possible discharges from spills and leaks from utilities and large industries in the RWQCP service area.
- Determine PCB levels in the water supply.
- Conduct additional testing of the landfill leachate and hazardous waste management facility discharges to the RWQCP.

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APPENDIX A

PCB Levels in Selected PCB-Containing Products

PCB Levels in Selected PCB-Containing Products

Product	Typical PCB Concentration (%)
NCR paper	3 to 5
Plasticizers in chlorinated rubber coatings for metals (used where chemical resistance or lack of electrical conductivity was important)	about 40 (optimal composition)
Polyvinylchloride (PVC) and chlorinated rubber paint	5 to 8
Boat paint	3 to 5
Thiokol rubber concrete joint sealant	1 to 40
Caulk in concrete joints in reservoirs (found in 84 of 178 reservoirs surveyed)	15 to 20
Cambric tape in high-voltage electrical cables	6 to 11
Microscopist's mounting media, refractive index liquid component and immersion oils	100
Fire-retardant lubricants in compressors on natural gas distribution systems (from which PCBs leaked into distribution systems, but according to EPA, not into homes)	88
High pressure gas pipeline grease	10

Source: Erickson, 1997

APPENDIX B

PCB-Related Regulations and Operations of the Electric Utility Industry

PCB-Related Regulations and Operations of the Electric Utility Industry

The largest number of transformers and capacitors in the RWQCP service area is probably held by the area's two electricity providers: the Palo Alto Utilities Department, which provides electricity for Palo Alto (excluding the portions of the Stanford University campus that are in Palo Alto); and Pacific Gas & Electric (PG&E), which provides electricity for all the surrounding areas in the RWQCP's service area, including Mountain View, Los Altos, Los Altos Hills, and East Palo Alto.

These utilities operate under the federal Toxic Substances Control Act (TSCA), which classifies any waste material with a PCB concentration of 50 ppm or higher as hazardous waste. California state law classifies any waste material with a PCB concentration of 5 ppm or higher as hazardous waste and requires that PCB spills be cleaned up to concentrations of no higher than 2 ppm. Regulations specific to transformers define those with concentrations higher than 500 ppm as PCB transformers and those with concentrations of 50 to 500 ppm as PCB-containing transformers. Transformers with concentrations under 50 ppm are not defined in TSCA regulations.

Transformers known to contain PCB concentrations of 500 ppm or higher were required by EPA to be replaced by Oct. 1, 1985, if they were near food or feed facilities, and to be on record at the nearest fire department if they were known to be in other locations. These transformer must remain registered until they are either replaced or retrofilled with oil having a PCB concentration less than 500 ppm. Transformers with PCB concentrations below 500 ppm are permitted to remain in service indefinitely.

In practice, when either PG&E or the Palo Alto Utilities Department removes a transformer from service, it is routinely tested for PCB content. If it has a concentration of 50 to 500 ppm, either it is drained and replaced with non-PCB oil, or both the body of the transformer and the oil are shipped to an out-of-state hazardous waste disposal facility. Any soil or equipment contaminated by a spill is also shipped to a hazardous waste disposal facility. If a transformer contains a PCB concentration between 5 and 50 ppm, it can be returned to service.

In 1984, PG&E completed a large transformer PCB replacement program throughout its service area. The program entailed replacing all network transformers with transformers containing less than 50 ppm PCBs. Network transformers are the largest type of transformer, servicing dense urban areas such as downtown San Francisco. (Other types of transformers include distributor transformers and substation transformers.) Since 1980, PG&E has operated under a policy of not installing any transformers with a PCB concentration over 5 ppm.

Some transformers with PCB concentrations higher than 500 ppm remain in service by each of the utilities serving the RWQCP service area (Griffith, 1997; Centola, 1997). Since all transformers that are currently in service have not been tested, they are not formally classified as transformers “known” to be PCB transformers. Both utilities cite the high cost of testing as a reason to not test transformers until they are taken out of service. PG&E estimates it could cost approximately \$200 million to test every transformer in its system.

Both utilities have systems to monitor and clean up spills, and representatives of both utilities say that in the 1990s, spills that exceed regulatory limits are very rare. In the 1990s, none of the transformer spills in the Palo Alto Utilities Department service area have been from PCB-containing transformers (Thomas, 1997). Furthermore, a very low percentage of transformers removed from service show PCB concentrations when tested. In 1996, of 210 transformers tested, one had a concentration over 500 ppm, five had concentrations between 5 and 50 ppm, and the rest did not have PCBs (Centola, 1997). In San Mateo County, spills occur about once per month but an estimated 1% exceed regulatory limits, according to Pete Griffith, PG&E’s consultant in charge of overseeing PCB regulatory compliance.

When spills occur from a PG&E transformer, PG&E routinely handles the spill as if PCBs are above the regulatory limits. All PCB-contaminated objects and materials used for clean-up, such as oils and solvents, and dirt or other contaminated materials are shipped out-of-state for hazardous waste disposal. Precautions are taken to prevent runoff into storm drains. For example, a spill of 5 gallons of oil with a PCB concentration of 80 ppm occurred in a San Mateo County homeowner’s yard. To take the most conservative approach possible to cleaning up the area, PG&E removed a 10-foot by 15-foot area of soil and sent it to a hazardous waste disposal facility (Griffith, 1997)

Transformer leakage has been cited as one of the major sources of PCBs to the atmosphere (Keeler et al., 1993); however, most such studies were conducted in the 1980s, and an unquantified number of PCB-containing transformers have since been removed from service by utilities. The overall emissions to the atmosphere from transformer leakage may still be high, although total quantities have been reduced since the mid-1980s.

Evaporation from transformer leakage and spills has been estimated at approximately 0.3% of spilled PCBs prior to cleanup (Keeler et al., 1993). An overall emission factor of approximately 7.2 mg for each kilogram of PCBs has been calculated for PCBs currently in transformers and capacitors. Therefore, if 5 gallons of transformer oil spilled, and it had a concentration of 50 ppm, and approximately 0.3% of the PCBs evaporated to the atmosphere prior to clean-up, approximately 0.28 grams of PCBs would reach the atmosphere from this spill.

Palo Alto's hazardous waste management program receives PCB-containing equipment from city facilities and households, such as fluorescent light ballasts. About 800 pounds per year of light ballasts are received, most of which do not contain PCBs. The equipment is sent to an Arizona facility that recycles light ballasts. Other PCB-contaminated material is sent to other out-of-state hazardous waste disposal facilities.

APPENDIX C

Calculations

STORM WATER INFLOW

Maximum PCB concentration in storm water = 1.0×10^{-6} grams per liter (g/l)
(Source: WCC, 1996)

RWQCP infiltration and inflow = 1.7×10^6 gallons per day (gal/day)
(Source: RWQCP 1997)

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

Maximum PCB load from storm water inflow =
 $(1.0 \times 10^{-6}$ g/l) x $(8.5 \times 10^5$ gal/day) x 3.785 l/gal x 0.002205 lb/g = 7.1×10^{-3} lb/day

Notes:

The concentration is based on 83 samples collected throughout Santa Clara Valley during 1988 and 1989 (WCC, 1996). PCBs were detected in 3 of the 83 samples. The detected values were 1.3, 1.4, and 1.4 micrograms per liter (ug/l), with a detection limit of 1 ug/l. If “non-detects” are assumed to equal zero, the average concentration was 0.048 ug/l. If “non-detects” are assumed to equal the detection limit, the maximum concentration was 1.0 ug/l.

WATER SUPPLY

Maximum PCB concentration in supply water = 0.5×10^{-6} g/l
(Source: SCVWD, 1997)

Total Wastewater Flow = 25.6×10^6 gal/day (Source: RWQCP 1997)
Groundwater Flow = 1.7×10^6 gal/day (Source: RWQCP 1997)
Infiltration and Inflow = 1.7×10^6 gal/day (Source: RWQCP 1997)

Supply Water Flow =
Residential + Commercial + Industrial = Total - Groundwater - Infiltration and Inflow =
 25.6×10^6 gal/day - 1.7×10^6 gal/day - 1.7×10^6 gal/day =
 22.2×10^6 gal/day

Maximum Water Supply Concentration =
 $(0.5 \times 10^{-6}$ g/l) x $(22.2 \times 10^6$ gal/day) x 3.785 l/gal x 0.002205 lb/g = **9.3×10^{-2}** lb/day

Notes:

Calculation is based on data provided by the Santa Clara Valley Water District, which provides 17% of the water for the RWQCP service area (SCVWD, 1997). The Santa Clara Valley Water District indicates that no PCBs have been detected above its detection limit for reporting, which is 0.5 ug/l. Data on PCBs below these levels are unavailable. Data are also unavailable for water from the San Francisco Water District (SFWD) system (75% of the supply) or local groundwater sources (8%). Water from the SFWD is likely to contain about the same or lower PCBs levels than water from Santa Clara Valley's Rinconada reservoir because most SFWD water comes from the remote and relatively well-protected Hetch Hetchy reservoir. Groundwater could potentially contain more PCBs than water from the Rinconada reservoir because of the greater potential for any possible PCB contamination in soils to infiltrate groundwater supplies.

LANDFILLS

The RWQCP collected 3 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 73 PCB congeners were measured with detection limits of 0.6 to 2.4 nanogram per liter (ng/l) per congener. Of the 73 congeners studied, only 6 were detected. Assuming that “non-detects” equal zero, the PCB concentration in the Palo Alto landfill discharge sample was about 200 ng/l. With a discharge flow of 11,679 gal/day, this concentration corresponds to a PCB load of about 2.0×10^{-5} lb/day.

Mountain View Landfill

The concentrations of each of 73 PCB congeners were measured with detection limits of 0.6 to 2.4 ng/l per congener. Of the 73 congeners studied, only 8 were detected. Assuming that “non-detects” equal zero, the PCB concentration in the Mountain View landfill discharge sample was about 500 ng/l. With a discharge flow of about 24,000 gal/day, this concentration corresponds to a PCB load of about 1.0×10^{-4} lb/day.

Cogeneration Facility

The PCB concentration was measured by U.S. EPA method 8080 (which covers 7 congeners) with a total PCB detection limit of 5 ug/l (ranging from 0.5 to 2.0 ug/l per congener). No PCBs were detected. With a discharge flow of about 50 gal/day, and assuming that the concentration of the sample equaled the detection limit, the PCB load would be no more than about 2.1×10^{-6} lb/day.

Total Landfill Discharge Load

$$2.0 \times 10^{-5} + 1.0 \times 10^{-4} + < 2.1 \times 10^{-6} = \mathbf{1.2 \times 10^{-4}} \text{ lb/day}$$

HAZARDOUS WASTE MANAGEMENT

The RWQCP collected one grab sample from the hazardous waste management facility in East Palo Alto. The concentrations of each of 73 PCB congeners were measured with detection limits of 0.6 to 2.4 ng/l per congener. Of the 73 congeners measured, only 11 were detected. Assuming that “non-detects” equal zero, the PCB concentration in the hazardous waste management discharge sample was about 580 ng/l. With a discharge flow of about 20,000 gal/day, this concentration corresponds to a PCB load of about **9.7 x 10⁻⁵ lb/day**.

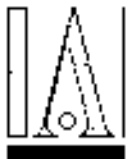
APPENDIX D

PCB Loads from Human Waste and Food Waste

Memorandum from Larry Walker Associates, not available in electronic form

MEMORANDUM

LARRY
WALKER



ASSOCIATES

DATE: September 30, 1997

TO: Kelly Moran, Palo Alto RWQCP

FROM: Betsy Elzufon and Astili Cooper, LWA

SUBJECT: PCB LOADS FROM FOOD AND HUMAN WASTES

Effluent limitations for polychlorinated biphenyls (PCBs) have existed in the Palo Alto Regional Water Quality Control Plant's (RWQCP) wastewater discharge permit since 1992. However, detection limits for these compounds in wastewater exceeded the limits until recently. In 1996, the RWQCP began monitoring for PCBs in their effluent and subsequently began an evaluation of PCB sources to the RWQCP. As part of this effort, daily loads of PCBs to the RWQCP from food and human waste were estimated. Table 1 compares the estimated PCB loads from food and human wastes to the estimated PCB loading in the RWQCP effluent.

Table 1. PCB Loads from Food and Human Waste

Total estimated PCB load from food waste (10^5 lb/day)	1.8
Total estimated PCB load from human waste (10^5 lb/day)	4.2
Total estimated PCB load (10^5 lb/day)	6
Total estimated RWQCP effluent load (10^5 lb/day)	6-70

Table 2 summarizes the calculations conducted to determine food and human waste PCB loads. The load from food waste was estimated by multiplying the amount of food waste disposed of annually by the levels of PCBs in the food. Estimates of food waste disposed were taken from the *Residential Metals Study* (LWA, 1994). Most of the concentrations of PCBs 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* (Schoeter, et. al., 1997). Values for the population of the RWQCP's service area were taken from *Projections '96: Forecasts for the San Francisco Bay Area to the Year 2015* (Association of Bay Area Governments, 1995). The estimated RWQCP effluent load is based on three effluent samples taken by the RWQCP during 1996 and 1997. Because of the small number of samples, the estimated effluent load is considered to be highly uncertain.

Unlike dioxins, PCB levels in food are equally distributed among different food types. Significant levels of PCBs were found in fatty foods, such as butter and hot dogs, and vegetables and grains

PCB Loads from Food and Human Wastes

September 30, 1997

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as well. The highest concentrations of PCBs were found in fresh fish. Hot dogs/bologna and butter have the highest PCB concentrations found in foods other than fish. However, estimates for the amounts of these foods disposed to the sewer system are not available. Estimates for the value of these foods disposed to the sewer would provide a more accurate estimate of the PCB load to the RWQCP from food waste.

PCB concentrations can be presented in a variety of ways. The numbers are most often presented as the sum of concentrations of congeners of similar type (i.e. co-planar PCBs) or in toxic equivalent concentrations. For the purpose of these calculations, the PCB values used were the sum of the concentrations of all congeners sampled. As a result, the values for PCB concentrations in food represent the sum of concentrations of 15 PCB congeners representing co-planar, mono-ortho, and di-ortho PCBs. The PCB concentration for human waste only includes co-planar PCB concentrations. Toxic equivalents were not used, although data is available in this form.

Most of the values for PCB levels in fruits or vegetables found were reported for fruits or vegetables in general, not for specific fruits or vegetables. Therefore, the food waste PCB 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 PCB excreted during a 24-hour period were taken from *Intake and Fecal Excretion of PCDDs, PCDFs, HCB and PCBs (138,153,180) in a Breast-Fed and Formula-Fed Infant* (Abraham, 1994). The values used represent the amount excreted by a five-month old breast-fed infant.

The estimates presented in Table 2 contain many uncertainties. The value for PCB concentrations in human waste is a value from an infant. The correlation between the amount of PCBs excreted by an infant and the amount excreted by children and adults is unknown. Therefore, the value for human waste is a highly uncertain estimate of the amount of PCBs coming from the residential

population. Additionally, the excretion rate is the sum of only three PCB congeners representing just di-ortho PCBs. Other PCB congeners may be present in feces which would increase the loads from human waste.

As described above, food disposal amounts are not available for several of the foods in which PCBs have been found. In addition to butter and hot dogs/bologna, food disposal values are also not available for pork. Although the amount of PCB that these foods would contribute to the load is uncertain, the missing values lead to an estimate of the PCB 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 PCB loads from food and human wastes.

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Table 2: Food and Human Waste PCB 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 PCB Conc. (pg/g food) ^(2,3)	PCB Loading (lb/day)
Beef	0.59	30.5	236200	980	1.19E-06
Chicken	0.86	44.8	236200	1040	1.86E-06
Pork				879	
Hot Dog/Bologna				3527	
Shellfish	0.14	7.2	236200	1758	5.03E-07
Fresh Fish	0.14	7.2	236200	7481	2.14E-06
Eggs	8.1	421	236200	211	3.55E-06
Butter				3254	
Cheese	0.07	3.6	236200	584	8.35E-08
Milk	2	104	236200	100 ⁽⁴⁾	4.15E-07
Fruit	1.4	73.5	236200	260 ⁽⁵⁾	7.63E-07
Green Vegetables	1.3	69.9	236200	635 ⁽⁵⁾	1.77E-06
Potato, Cereal, Grain	1.6	82.5	236200	1000 ⁽⁵⁾	3.29E-06
Rice	0.86	44.8	236200	1517 ⁽⁵⁾	2.71E-06
TOTAL FOOD WASTE LOAD (lb/day)					1.83E-05
B. HUMAN WASTE CALCULATION					
			Population	Excretion (pg/day/cap) ⁽⁷⁾	
HUMAN WASTE LOAD (lb/day)			236200	81000	4.21E-05
TOTAL LOAD (Human and Food Waste) (lb/day)					6.04E-05
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 (Scheeter, 1997) unless otherwise stated.					
(3) Concentrations represent the sum of 15 coplanar, mono-ortho and di-ortho PCB congeners.					
(4) Levels of specific polychlorinated biphenyl congeners in fatty foods from five Canadian cities between 1986 and 1988 (McC, 1991).					
(5) Dietary Intake of Dioxin-Related Compounds through Food in Japan (Takayama, 1991)					
(6) 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).					
(7) Intake and Fecal Excretion of PCDDs, PCDFs, HCB and PCBs (138, 153, 180) in a Breast-fed and a Formula-fed Infant (Abraham, 1994)					

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