

Fact Sheet: Sources of Polychlorinated Biphenyls

Purpose

This fact sheet is intended to help Oregon Department of Environmental Quality (DEQ) project managers and City of Portland stormwater inspectors understand the types of industries, processes, and products that might be potential sources of polychlorinated biphenyls (PCBs). There are a variety of potential PCB sources in addition to more commonly recognized sources such as electrical transformer and capacitor oils and fluorescent light ballasts.

Background

PCBs are mixtures of synthetic organic chemicals that were commonly used for various applications from approximately 1929 until 1979 when the U.S. banned PCB manufacturing, processing, distribution, and use (EIP Associates, 1997). The U.S. was responsible for approximately half of the world's production of PCBs and imported approximately 50% of the remainder produced by other countries (minus exports) (EIP Associates, 1997; UNEP Chemicals, 1999). PCBs were produced and marketed in the U.S. under the trade names of Aroclor (produced by Monsanto Chemical Company) and Pyranol (produced by General Electric) (Nagpal, 1992). Because of health concerns, in 1971 Monsanto voluntarily restricted manufacturing of PCBs to use only in closed systems. Monsanto discontinued manufacture of PCBs in 1977, though PCBs continued to be imported into the U.S. until 1979 when the U.S. ban took effect (EIP Associates, 1997; ATSDR, 2000).

There are no natural sources of PCBs. Although their current commercial use is restricted in the U.S., they continue to be a common environmental contaminant because they are extremely stable.

Regulatory Framework

PCBs were regulated under a series of EPA actions culminating with a ban in 1979 on manufacturing, processing, distribution, and use of PCBs under the Toxic Substances Control Act (TSCA). Items such as transformers and hydraulic fluids were identified as high-risk sources and were targeted for accelerated phase-out. EPA anticipated that other lower-risk sources would eventually be removed from circulation as various products reached the end of their useful lives.

Certain current uses of PCBs are authorized under 40 CFR Part 761 and are summarized in Table 1:

TABLE 1	
Current Authorized Uses of PCBs	
Use	Comments
Transformers	Authorized use at any concentration though restrictions and regulatory requirements increase with higher PCB concentration thresholds.
Railroad Transformers	Transformers used in locomotives and self-propelled railcars. Authorized use at < 1,000 ppm; < 50 ppm if transformer coil is removed at any time.
Heat transfer systems, hydraulic systems, mining equipment	Authorized use at < 50 ppm
Natural gas pipelines	Authorized at < 50 ppm, or at > 50 ppm with additional requirements. PCBs may be present in natural gas compressors, scrubbers, filters, and in condensate.
Research & Development	Authorized primarily for purposes relating to environmental analysis, management, and disposal of PCBs. R&D for PCB products is prohibited.
Scientific Instruments	Examples include oscillatory flow birefringence & viscoelasticity instruments for the study of the physical properties of polymers, microscopy mounting fluids, microscopy immersion oil, and optical liquids.
Carbonless copy paper	Use of existing carbonless copy paper is permitted; manufacturing of new carbonless copy paper is not authorized.
Electromagnets, switches, voltage regulators, circuit breakers, reclosers, cable	No restrictions on existing use; restrictions on PCB concentrations if serviced and oil is removed or replaced.
Porous surfaces	EPA considers building materials, such as concrete, porous with respect to PCB leaks and spills. Porous building materials may be left in place following spills provided various conditions are met. Older industrial machinery often was designed to slowly leak (PCB-containing) hydraulic oil as a lubricant.
Source: EPA (2002)	

Under 40 CFR Part 761, recycled PCBs are defined as "those PCBs which appear in the processing of paper products or asphalt roofing materials from PCB-contaminated raw materials". Recycled PCBs are subject to the following restrictions:

- ❑ No detectable concentrations of PCBs are permitted in asphalt roofing materials that leave the manufacturing site; and
- ❑ Manufactured and imported paper products must have an annual average of less than 25 ppm PCBs with a maximum of 50 ppm.

Some manufacturing processes may inadvertently generate PCBs. These typically include chemical processes that involve hydrocarbons, chlorine, and heat. Typical processes include production of chlorinated solvents, paints, printing inks, agricultural chemicals, plastics, and detergent bars. These processes may be defined as "excluded manufacturing processes" under 40 CFR Part 761 if the following conditions are met:

- Manufactured or imported products must contain < 25 ppm PCBs;
- Manufactured or imported detergent bars must contain < 5 ppm PCBs;
- PCB concentrations must be less than 10 ppm at the point which PCBs are released to ambient air;
- "...PCBs added to water discharged from a manufacturing site must be less than 100 micrograms per resolvable gas chromatographic peak per liter of water discharged"; and
- Disposal of process wastes with PCB concentrations > 50 ppm must be conducted in accordance with 40 CFR Part 761 Subpart D.

Sources of PCBs

In the U.S., the most commonly used Aroclors were: 1221, 1232, 1242, 1248, 1254, and 1260 (DEQ, 1997). These and other Aroclors were used in a variety of materials to enhance insulative properties, improve physical and chemical resistance, and act as plasticizers, coolants, and lubricants. Additional information about specific Aroclors is included in Table A-1 (see Attachment 1).

Approximate usage of PCBs in the US is summarized as follows (EIP Associates, 1997):

Closed system and heat transfer fluids (transformers, capacitors, fluorescent light ballasts, etc.): 60%

Plasticizers: 25%

Hydraulic fluids and lubricants: 10%

Miscellaneous uses: 5%

As shown in Table 2, PCBs were commonly used in a number of electrical, heat transfer, and hydraulic applications as well as a range of other applications.

TABLE 2	
PCB Uses	
Primary Applications	
Dielectric fluids and transformers	Used as insulating material, coolant, and for fire-resistant properties. Potential sources would be facilities which used, stored, and serviced electrical equipment and which used significant amounts of electricity. These facilities could include, but are not limited to: Electrical transmission and distribution facilities; electrical equipment maintenance facilities and salvage yards; rail yards; and manufacturing facilities (sawmills, pulp and paper mills, chemical manufacturing, shipyards, primary and secondary metals smelting and refining, etc.)
Capacitors	Present in industrial facilities, industrial machinery both fixed and mobile, and consumer products. Includes larger power-factor correction capacitors associated with transformers, manufacturing facilities, and commercial buildings (usually near high power-usage equipment such as computer rooms and heating and cooling units); and smaller electric motor-start capacitors used in industrial

	equipment and appliances such as hair dryers, air conditioners, refrigerators, power tools, and submersible well pumps. Also includes capacitors used in appliances and electronics such as televisions and microwave ovens.
Fluorescent light ballasts	PCB-containing capacitors were used in fluorescent light ballasts. PCB-containing asphaltic resin (potting material) was also utilized as insulating material for some ballasts.
Electromagnets	Oil-cooled electromagnets are constructed with coils immersed in transformer oil to prevent over-heating and shorting. Used in cranes for picking up metal and for metal separation in recycling operations (metal scrap yards, tire shredding, concrete crushing, slag operations, etc.).
Miscellaneous electrical equipment	Switches, voltage regulators, circuit breakers, reclosers, rectifiers, and some oil-cooled electric motors.
Heat transfer systems	Where oil is circulated through a non-contact system as a heat transfer medium for heating, cooling, and maintaining uniform temperature throughout a system or manufacturing process. Wide variety of applications in manufacturing industries including high-tech, asphalt, pulp and paper, metal products such as steel tubing and die casting, adhesives, chemicals, food processing, paint & coatings, textiles, etc.
Hydraulic fluids	Any application of hydraulic oil such as industrial equipment and machinery, commercial equipment, automotive brake fluid, etc.
Plasticizers	Used in polyvinyl chloride plastic, neoprene, chlorinated rubbers, laminating adhesives, sealants and caulking, joint compounds (concrete), etc.
Lubricants	Cutting oils, compressors, electrical equipment, oil-impregnated gaskets and filters; also currently present in low concentrations in recycled oil. Also used in vacuum pumps at high tech and electronics manufacturing facilities, research labs, and wastewater treatment plants.
Other applications of PCBs	
Dust control (dedusting agents)	Present in dust control formulations, and used oil historically used for dust suppression.
Pesticides	As an extender to extend the life of pesticides.
Fire retardants	Coatings on ceiling tiles, and textiles including ironing boards and yarn.
Paints, coatings	As plasticizers in paint, corrosion resistant paints for various applications including military/navy ships, corrosion resistant epoxy resins on metal surfaces, film casting solutions for electrical coatings, varnish, lacquers, and waterproofing coatings for various applications.
Carbonless copy paper	Used as an ink pigment carrier (microencapsulation of dye); when the top sheet was pressed down, ink and PCB oil were transferred to the copy.
Printing inks	Ink for newsprint and as a dye carrier; also used as a solvent for deinking newsprint for recycling.
Investment casting waxes	Used as wax extenders.
Wood treatment	May be present as an impurity in pentachlorophenol (Warrington, 1996).
Sources: ATSDR (2000), DEQ (1997), EIP Associates (1997), UNEP Chemicals (1999)	

Due to the long service life of many PCB-containing items and the use of PCBs in some durable, relatively inert products, PCB-containing materials will continue to be disposed of and processed in waste and recycling operations. Waste products and recycling operations that may process significant quantities of PCB-containing materials are described in Table 3:

TABLE 3	
PCB Sources In Waste Materials And Recycling Operations	
Material or Operation	Comments
Scrap metal recycling	Transformer shell salvaging; heat transfer and hydraulic equipment; and fluff (shredder waste from cars and appliances including upholstery, padding and insulation). Also present in non-ferrous metal salvaging as parts from PCB-containing electrical equipment, and oil & grease insulated electrical cable.
Auto salvage yards, auto crushing	Hydraulic fluid, brake fluid, recycled oil, capacitors, and oil-filled electrical equipment such as some ignition coils.
Repair activities	Shipyards (electrical equipment, hydraulic oil, paint, etc.), locomotive repair, heavy equipment repair facilities, auto repair, repair of manufacturing equipment, etc.
Used oil	May be present in used oil from various sources including auto salvage yards, automotive and heavy equipment repair shops, hydraulic equipment repair, industrial machinery repair, etc. Because some PCBs have been mixed with used oil, some recycled oils currently in circulation may contain PCBs at concentrations generally < 50 ppm. PCBs may also be present where used oil has been used for dust suppression/road oiling, weed control, and energy recovery.
Recycled paper	Paper may contain PCBs where carbonless copy paper has been used in recycling. However, PCB concentrations have decreased over time as the volume of unrecycled carbonless copy paper is reduced. Recycled paper containing PCBs has historically been used for food packaging (CWC, 1997). PCB concentrations in food packaging are restricted to 10 ppm unless an impermeable barrier is present between the packaging and food product (FDA, 2003).
Effluent	PCBs may be in wastewaters from manufacturing facilities and equipment such as chemical and pesticide facilities, pulp and paper mills, cooling waters from vacuum pumps and electric power generation facilities where leaks have occurred, and condensate from vacuum pumps and natural gas pipelines. Significant cleanup activities have been performed at natural gas pipeline compressor stations from discharges of condensate to ground and storm drainage systems (DOJ, 2002).
Asphalt roofing materials, tar paper, and roofing felt	Anticipated at generally very low concentrations where used oil containing PCBs has been used in asphalt mix.
Building demolition	Electrical equipment, joint caulking, oil & grease insulated cable, surface coatings as flame retardant and waterproofing.
Dredge spoils	From areas where contaminated sediments are present.
Landfills	Municipal and industrial solid waste; virtually all potential sources could be present, including waste materials and soils from remediation sites.
Wastewater treatment plant sludge	Derived from atmospheric deposition and stormwater, water supply systems, leaks and spills, leaching from coatings and plastics containing PCBs, PCBs in food and human waste.
Sources: EIP Associates (1997), EPA (2002), UNEP Chemicals (1999)	

Releases of PCBs

Prior to the regulation of PCBs under the Toxic Substances Control Act (TSCA) in 1976, PCBs were released (both accidentally and intentionally) into the atmosphere, water, and land through sewers, smokestacks, stormwater runoff, spills, and direct application to the environment (for example, to reduce dust emissions and to extend the life of some agricultural pesticide formulations) (Flynn, 1997). Large volumes of PCBs have been introduced to the environment through the burning of PCB-containing products, vaporization from PCB-containing coatings and materials, releases into sewers and streams, improper disposal of PCB-containing equipment in non-secure landfill sites and municipal disposal facilities, and by other routes (such as ocean dumping) (ATSDR, 2001).

Based on the current regulation of PCBs, the current primary "new" sources of PCB contamination are limited to outdated or illegal landfills and scrap yards and leaks or explosions of electrical equipment and other equipment (such as locomotive transformers) that may still contain PCBs (ATSDR, 2001). Other sources are facilities or sites that were previously contaminated with PCBs (for example, contaminated sediments). From contaminated sites, PCBs are emitted and re-deposited to the environment via volatilization from water and soil, wet and dry depositions, and revolatilization (HSDB, 2003). These processes are discussed in further detail in Attachment 2.

Attachment 1 – Common Uses of Aroclors

Common uses of specific Aroclors are shown in Table A-1.

TABLE A-1	
Common Uses of Aroclors	
Aroclor Type	Use and Comments
A-1016	Capacitors
A-1221	Capacitors Gas Transmission Turbines Rubber Polyvinyl acetate - Improved quick-track and fiber-tear properties Polystyrene – Plasticizer Epoxy resins - Increased resistance to oxidation and chemical attack; better adhesive properties
A-1232	Hydraulic fluid Rubber Adhesives Polyvinyl acetate - Improved quick-track and fiber-tear properties
A-1242	Transformers Heat transfer Hydraulic fluid Gas transmission turbines Rubbers Carbonless copy paper Wax extenders Polyvinyl acetate - Improved quick-track and fiber-tear properties
A-1248	Hydraulic fluids Vacuum pumps Rubbers Polyvinyl chloride - Secondary plasticizers to increase flame retardence and chemical resistance Epoxy resins - Increased resistance to oxidation and chemical attack; better adhesive properties
A-1254	Transformers Capacitors

TABLE A-1 Common Uses of Aroclors	
Aroclor Type	Use and Comments
	Hydraulic fluids Vacuum pumps Synthetic resins Wax extenders Dedusting agents Inks Cutting oils Pesticide extenders Sealants and caulking compounds Polyvinyl chloride - Secondary plasticizers to increase flame retardence and chemical resistance Styrene-butadiene co-polymers - Better chemical resistance Ethylene vinyl acetate – Pressure-sensitive adhesives Chlorinated rubber - Enhanced resistance, flame retardence, electrical insulation properties
A-1260	Transformers Hydraulic fluids Dedusting agents Polyvinyl chloride - Secondary plasticizers to increase flame retardence and chemical resistance Polyester resins - Stronger fiberglass; reinforced resins and economical fire retardants Varnish - Improved water and alkali resistance
A-1262	Synthetic resins Crepe rubber - Plasticizers in paints Nitrocellulose lacquers - Co-plasticizers Wax - Improved moisture and flame resistance
A-1268	Rubbers Synthetic resins Neoprene - Fire retardant; injection moldings Wax extenders
Sources: Nagpal (1992); ATSDR (2000).	

Attachment 2 – Fate and Transport of PCBs

The basic chemical structure of PCBs includes two benzene rings (known as the biphenyl) and between 1 and 10 chlorine atoms substituted on each of the benzene molecules. Figure 1 shows the basic structure of PCBs, where the numbers 2-6 and 2'-6' represent possible substitution locations for chlorine. There are a total of 209 individual PCB compounds (known as congeners) (Flynn, 1997). Typically, PCBs occur as mixtures of congeners (that is, Aroclors) (Bernhard and Petron, 2001). Aroclors are identified by number (such as 1254), with the last two digits representing the percent content of chlorine; higher Aroclor numbers reflect higher chlorine content (ATSDR, 2001).

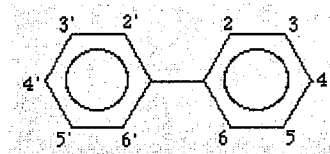


Figure 1. Basic PCB Structure

As discussed in the main text of this fact sheet, PCBs were emitted in large quantities before PCB manufacturing was banned in the U.S. Between 1930 and 1970, approximately 30,000 tons were released to air, 60,000 tons to fresh and coastal waters, and 300,000 tons to dumps and landfills (HSDB, 2003). Because of their extreme chemical and thermal stability, once they are introduced to the environment they remain there for years or even decades (ATSDR, 2000).

PCBs are nonpolar and therefore are only slightly soluble. This characteristic inhibits the transport of PCBs from soil to water (groundwater or surface water) and makes them bind strongly to soils. PCBs can be transported to surface water via entrainment of contaminated soil particles in surface water runoff. In water, a small portion of PCBs will dissolve, but the majority will bind to organic particles and bottom sediments (Nagpal, 1992). Although PCBs have a strong affinity for sediment, small amounts of PCBs are released from sediments to water over time (ATSDR, 2000). Once in the water, PCBs are also taken up by small organisms and fish. PCBs accumulate in the fatty tissue of these organisms.

PCBs have a relatively low vapor pressure. Despite their low volatility, PCBs do volatilize from both soil and water. This is a result of their widespread presence and extreme stability (DEQ, 1997). Once re-emitted, PCBs can be transported long distances in air, and then redeposited by settling or scavenging by precipitation. This cycling process continues indefinitely and is referred to as the grasshopper effect (EPA, 2001). It is estimated that there are currently 1,000 tons of PCBs cycling through the atmosphere over the U.S. (HSDB, 2003). Studies performed at Lake Michigan show that 80 percent of the PCBs entering the lake come from the air (Delta Institute, 2000). Additional evidence of the atmospheric deposition of PCBs is the presence of PCBs in sparsely populated areas of Canada and in Arctic polar bears (both far from point sources of PCB contamination) (Fiedler, 1997).

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