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Guidelines for the Identification of PCBs and Materials Containing PCBs

First Issue
August 1999

Prepared by UNEP Chemicals

IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

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Preface

This document continues UNEP's work in developing and publishing information on polychlorinated biphenyls (PCBs) that began last year with the publication of UNEP's "Inventory of World-wide PCB Destruction Capacity." PCBs are chemical substances which are persistent, bioaccumulate, and pose a risk of causing adverse effects to human health and the environment. They can be transported long distances, and have been detected in the furthest corners of the globe, including places far from where they were manufactured or used. While manufacture of PCBs has reportedly ceased, the potential or actual release of PCBs into the environment has not, since significant quantities of existing PCBs continue in use or in storage.

The likely extended period of these continuing uses, and the persistence of PCBs once released into the environment together mean that PCBs could pose a threat for decades to come. Accordingly, UNEP's Governing Council included PCBs among the 12 persistent organic pollutants (POPs) identified for international action.

The Council, at its nineteenth session in February 1997 concluded that international action, including a global legally binding instrument, is required to reduce the risks to human health and the environment arising from the release of the 12 POPs (PCBs, dioxins and furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor). It requested UNEP to prepare for and convene by early 1998 an intergovernmental negotiating committee (INC), with a mandate to prepare an international legally binding instrument for implementing international action, beginning with the 12 POPs. The Council also requested UNEP to initiate a number of immediate actions, including intensifying POPs information exchange; improving the availability of information on alternatives to POPs; developing an inventory of PCB destruction capacities and assisting countries in identifying PCBs; and assisting countries in identifying dioxin and furan sources.

To promote the development and sharing of information on the twelve specified POPs, UNEP has established a network of government designated focal points for exchanging technical information and obtaining expertise for the development of various products. Information on available PCB-destruction facilities from these focal points and other sources, notably from the Secretariat of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, was incorporated into UNEP's inventory of the worldwide capacity to destroy PCBs, as published in December 1998. That inventory lists facilities that can store, handle and dispose of PCBs in various forms, and should provide a useful tool for national authorities and others concerned with the management of PCBs.

This companion publication, "Guidelines For the Identification of Materials Containing PCBs," fulfills the second part of the UNEP Governing Council's request that UNEP develop and publish information to assist countries in ensuring the environmentally sound management of PCBs. It provides information on the known names, characteristics, and uses for PCBs, as well as on sampling and analysis techniques to indicate their presence. Any views expressed in the document do not necessarily reflect those of UNEP Chemicals.

UNEP thanks donor countries, especially Germany, Norway, and the USA, for their contributions, through which the production of this document was made possible. Both this publication and its companion publication on worldwide capacity to destroy PCBs (see above), should be considered dynamic and will be updated as new information becomes available. Accordingly, UNEP Chemicals welcomes information or suggestions which could be incorporated into future revisions of both documents.

Klaus Töpfer
Executive Director
United Nations Environment Programme

1. INTRODUCTION

The term polychlorinated biphenyls, or PCBs, refers to a class of synthetic organic chemicals that are, to a large degree, chemically inert. PCBs have been widely used as additives to oils in electrical equipment, hydraulic machinery, and other applications where chemical stability has been required for safety, operation, or durability. Although the chemical stability of many PCBs has been a benefit from the standpoint of commercial use, it has created an environmental problem because it translates into extreme persistence when the PCBs are eventually released into the environment. In fact, PCBs are among the most widespread environmental pollutants, having been detected in virtually all environmental media (indoor and outdoor air, surface and ground water, soil, and food) in almost every corner of the globe. Not only are PCBs often persistent, but many PCB-mixtures are also toxic. Exposure to low levels of PCBs is thought to cause various acute and chronic health effects.

Protection of human health and the environment requires that PCBs be disposed of in such a way that they do not enter the environment. The first step in the environmentally sound management of PCBs is to identify their sources and develop strategies for reducing or eliminating their release into the environment. The purpose of this document is to provide guidance on identifying PCBs and PCB-containing materials through information on general applications, specific sources, and typical locations of equipment and materials that contain PCBs. Additionally, tests to determine the actual presence of PCBs, as well as storage and disposal options are identified.

It should be noted that this document is considered to be a work in progress. The examples and information presented in this report were drawn from documents available to UNEP Chemicals and other sources that are currently accessible through library and Internet search engines. Readers are invited to forward new or additional information to UNEP Chemicals so that it may be incorporated in future revisions of this document.

The document is organized as follows:

- **Section 2 - Background**: Provides general information on PCBs, including definition, uses, physical and chemical characteristics, and effects on the environment and human health.
- **Section 3 - Initial Identification of Potential PCB-Containing Materials**: Provides a more detailed discussion of the end-uses of PCBs focusing on likely PCB locations and potential PCB-containing materials (including wastes). Uses are designated as closed, partially closed, and open applications.
- **Section 4 - PCB Presence and Concentration Tests**: Provides various analytical tests for assessing PCB presence in suspect products and other media (e.g., waste, soil, paint, etc.).
- **Section 5 - Interim Storage and Permanent Disposal**: Provides a brief introduction to the current options for the storage and disposal of PCB-containing products and waste.
- **Annex A – Step-by-Step Approach for PCB Identification**: Provides a general road map for PCB identification using a series of easy reference tables. This annex is intended as a quick reference tool to be used in conjunction with the main document, especially Sections 3 and 4.
- **Annex B - Sources of Additional Information**: Provides listings of organizations and websites that can provide further guidance on PCBs.
- **Annex C - Compendium of Relevant Documents**: Provides brief summaries of significant documents relating to the identification and management of PCB-containing materials.

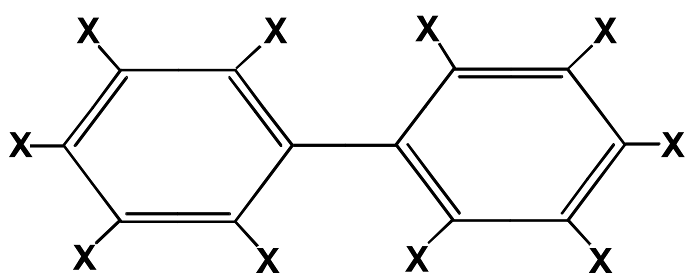
2. BACKGROUND

2.1 The Definition of PCBs and the Distribution of PCB Uses

Polychlorinated biphenyls or PCBs are a subset of the synthetic organic chemicals known as chlorinated hydrocarbons. The chemical formula for PCBs is $C_{12}H_{(10-n)}Cl_n$, where n is a number of chlorine atoms within the range of 1-10. The class includes all compounds with a biphenyl structure (i.e., two benzene rings linked together) that have been chlorinated to varying degrees. Theoretically, a total of 209 possible PCB congeners exist, but only about 130 of these are likely to occur in commercial products (Neumeier 1998). Commercial PCBs are a mixture of 50 or more PCB congeners.

PCB Molecular Structure

The structure below represents a PCB molecule. Note that each position on the rings can be substituted with a chlorine atom (i.e., each PCB molecule can contain up to ten chlorine atoms).



$C_{12}H_{(10-n)}\ Cl_n$ X = H or Cl

PCBs have been produced on an industrial scale for more than fifty years and have been exported as chemicals and in products to virtually every country in the world. Countries that have manufactured PCBs include Austria, China, Czechoslovakia, France, Germany, Italy, Japan, the Russian Federation, Spain, the United Kingdom, and the United States (Fiedler 1997; Jakobi 1996; Environment Canada 1985). PCBs were commonly used as dielectric fluids[1] in transformers and capacitors, in heat transfer and hydraulic systems, and as ink solvents in carbonless copy paper. Other uses of PCBs included the formulation of lubricating and cutting oils, as plasticizers in paints, in adhesives, in sealants, as flame retardants, and in plastics. An extensive review of the uses of PCBs is provided in Section 3 with supporting documentation appended in Annex A.

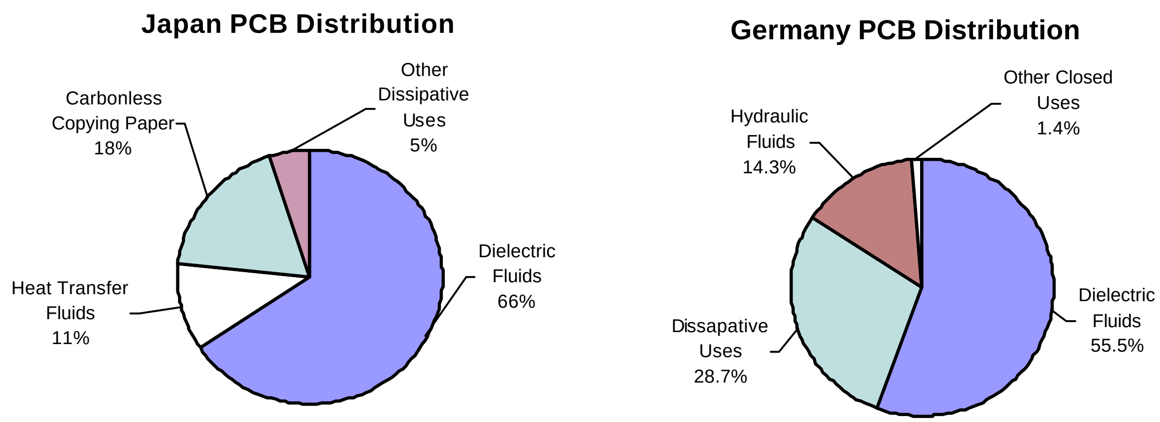
As an indication of possible PCB-use areas for concentrated environmental management efforts, Figure 1 provides representative distributions of end-uses for PCBs manufactured in Germany and Japan. These PCB fluids were sold to various manufacturers, and some of the products that contained PCBs were exported to developed and developing nations. In both countries, sale for use as dielectrics (mostly in transformers and capacitors) represented well over half of all PCB-use (Dobson and van Esch 1993; Neumeier 1998). Data on PCB end-uses in the United States provides similar results. In 1970, 56 percent of the PCBs manufactured in the U.S. were used in dielectric fluids. The next largest use was plasticizers (primarily carbonless copy paper) at 30 percent, followed by hydraulic fluids and lubricants with 12 percent. By 1971, U.S. PCB sales for dielectrics had risen to comprise 77 percent as a result of voluntary restrictions on sales for dissipative uses (Dobson and van Esch 1993).

[1] A fluid that does not conduct electricity.

2.2 PCB Attributes and Effects on the Environment and Health

PCBs have many useful physical and chemical properties that have led to their widespread use. PCB attributes include fire resistance, low electrical conductivity, high resistance to thermal breakdown, high degree of chemical stability, and resistance to many oxidants and other chemicals (Dobson and van Esch 1993; Fiedler 1997). PCBs are insoluble in water, but dissolve easily in fats, hydrocarbons, and other organic compounds (Dobson and van Esch 1993; Fiedler 1997). The thermal and chemical stability that makes PCBs so useful in industrial applications, however, leads to significant potential impacts to the environment and human health.

Figure 1: Historical PCB Distribution Among German and Japanese Manufacturers[2]



Source: Data obtained from Dobson and van Esch 1993; Neumeier 1998.

As previously stated, commercial PCBs consist of a mixture of PCB congeners, the most abundant of which tend to be readily degradable. A smaller portion of PCB congeners, however, tend to be “dioxin-like” PCBs, which are very stable and resistant to biodegradation and metabolism. These latter congeners have been found in all environmental matrices. Relatively large amounts were released due to inappropriate disposal practices, accidents, and leakage from industrial facilities. Significant amounts of PCBs were and are still released via diffuse emissions from industrial facilities (Fiedler 1997).

Furthermore, PCB exposure in the environment is often from the redistribution of previously released PCBs. The redistribution cycle involves volatilization from water into the atmosphere with subsequent transport in air and removal from the atmosphere via wet/dry deposition of PCBs, especially higher chlorinated biphenyls, bound to particulates and subsequent re-volatilization (Dobson and van Esch 1993).[3]

PCBs bio-accumulate in the fatty tissues of exposed animals and humans (Ponnambalam 1998; Neumeier 1998; Fiedler 1997) and this exposure is believed to be responsible for a wide variety of health effects. Acute exposures to high levels of PCBs have been associated with skin rashes, itching and burning, eye irritation, skin and fingernail pigmentation changes, disturbances in liver function and the immune system, irritation of the respiratory tract, headaches, dizziness, depression, memory loss, nervousness, fatigue, and impotence (Environment Canada 1985). Chronic effects of

[2] PCB manufacturers distribute to end-use industries that in turn export products worldwide.
[3] PCBs are very immobile in soils where the organic carbon acts as a natural sink for unpolar lipophilic substances (such as PCBs).

low-level PCB exposures reported include liver damage, reproductive and developmental effects, and possibly cancer. The US Department of Health and Human Services as well as the International Agency for Research on Cancer (IARC) consider PCBs to be probable carcinogens in humans (ATSDR 1997; IARC 1987). Much of the data on effects of PCB exposure on humans comes from incidents of PCB contamination in cooking oil or food or from the long-term exposure to PCBs of capacitor manufacturing workers (IARC 1987; ATSDR 1989).

2.3 Classification by PCB Concentration

Many countries have developed classification systems for PCB-containing fluids and materials. These systems are useful tools for prioritizing PCB management activities, as well as for establishing safe use and working conditions. Two example classification schemes for PCBs are shown at the right.

Example Classifications by Concentration

Presented below are two different types of PCB classification systems. The ppm system is based on regulations in place for the United States. The percent by weight system is based on regulations in place for Sweden. Note that 0.1 percent by weight = 1000 ppm.

Parts Per Million (PPM)

- > 500 ppm = regulated "pure" PCB substance
- 50 to 500 ppm = regulated PCB contamination
- 5 to 50 ppm = potentially regulated PCB contamination
- < 5 ppm = non-PCB

Percent by Weight

- 0.1 percent by weight = regulated PCB contamination

PCB regulations generally apply to equipment containing:

- > 500 litres of > 0.1 percent by weight PCB fluid; or
- > 0.5 kgs of 100% PCB fluid

Sources: (Goodwin 1998; Swedish OHSB 1985; Neumeier 1998)

Many countries, including Australia, Canada, Germany, Sweden, the United Kingdom, and the United States, consider materials with 50 ppm (parts per million by weight, also expressed as milligrams per kilogram, or mg/kg) PCBs as the benchmark level for PCB regulation. In these countries, materials with greater than 50 ppm PCBs generally must be handled in accordance with their specific PCB regulations.

PCB concentration levels are also pertinent in determining the necessary disposal method. For example, PCB-containing capacitors and transformers tend to have PCB concentrations of well over 500 ppm. Most countries regulating PCBs require that products containing high concentrations be disposed of by specific methods (e.g., incineration).

3. Initial Identification of Potential PCB-Containing Materials

Increasing awareness about the health and environmental effects associated with PCB exposure has resulted in a gradual withdrawal of use and an increase in production restrictions. Despite these efforts, PCBs continue to enter the environment. This is especially true for developing nations that may have large quantities of PCB-containing electrical equipment still in service. This section provides guidance on identifying PCB materials by end-use and type of waste. Where feasible, PCB-containing materials are described according to general application, specific end-use, and typical location (e.g., mining operations, electric utilities, etc.).

Provided below is a step-by-step approach to PCB identification using several specified guidance tables. These directions refer to tables and text provided in both Annex A and the main document. Tables beginning with the letter “A” are located in Annex A. All other tables and sections noted are located in the main document. The step-by-step approach is repeated in Annex A.

Step-By-Step Approach to PCB Identification

Step 1. Determine possible target locations for PCB inspection. Consult:

- Table A.1 PCB Applications by Location

Step 2. At the target location(s), determine potential PCB-containing applications. Consult:

- Table A.1 PCB Applications by Location
- Section 3 Initial Identification of Potential PCB-Containing Materials

Step 3. For all transformers and capacitors, inspect equipment for initial indication of PCBs. Match equipment with manufacturing companies’ information on PCB-containing products. Consult:

- Table A.2 PCB-Containing Transformer Manufacturing Companies
- Table A.3 PCB-Containing Capacitors
- Section 3.1.1 Closed Applications
- Manufacturers’ Literature, Maintenance Records, and Trade Associations

Step 4. For other closed and partially closed applications and unclassified transformers and capacitors, inspect for indications of PCB mixture trade names. Consult:

- Table A.4 Trade Names and Synonyms for PCB Mixtures
- Section 3 Initial Identification of Potential PCB-Containing Materials
- Manufacturers’ Literature, Maintenance Records, and Trade Associations

Step 5. For potential PCB-containing open applications, consult:

- Table 3 Open Applications of PCBs (page 9 of the main document)
- Section 3.1.3 Open Applications

Step 6. At the target location(s), determine potential PCB-containing wastes. Consult:

- Table A.5 PCB-Containing Wastes
- Section 3.2 PCB-Containing Wastes

Step 7. Test the identified closed, partially closed, and open applications, and wastes for the actual presence and concentration of PCBs. Consult:

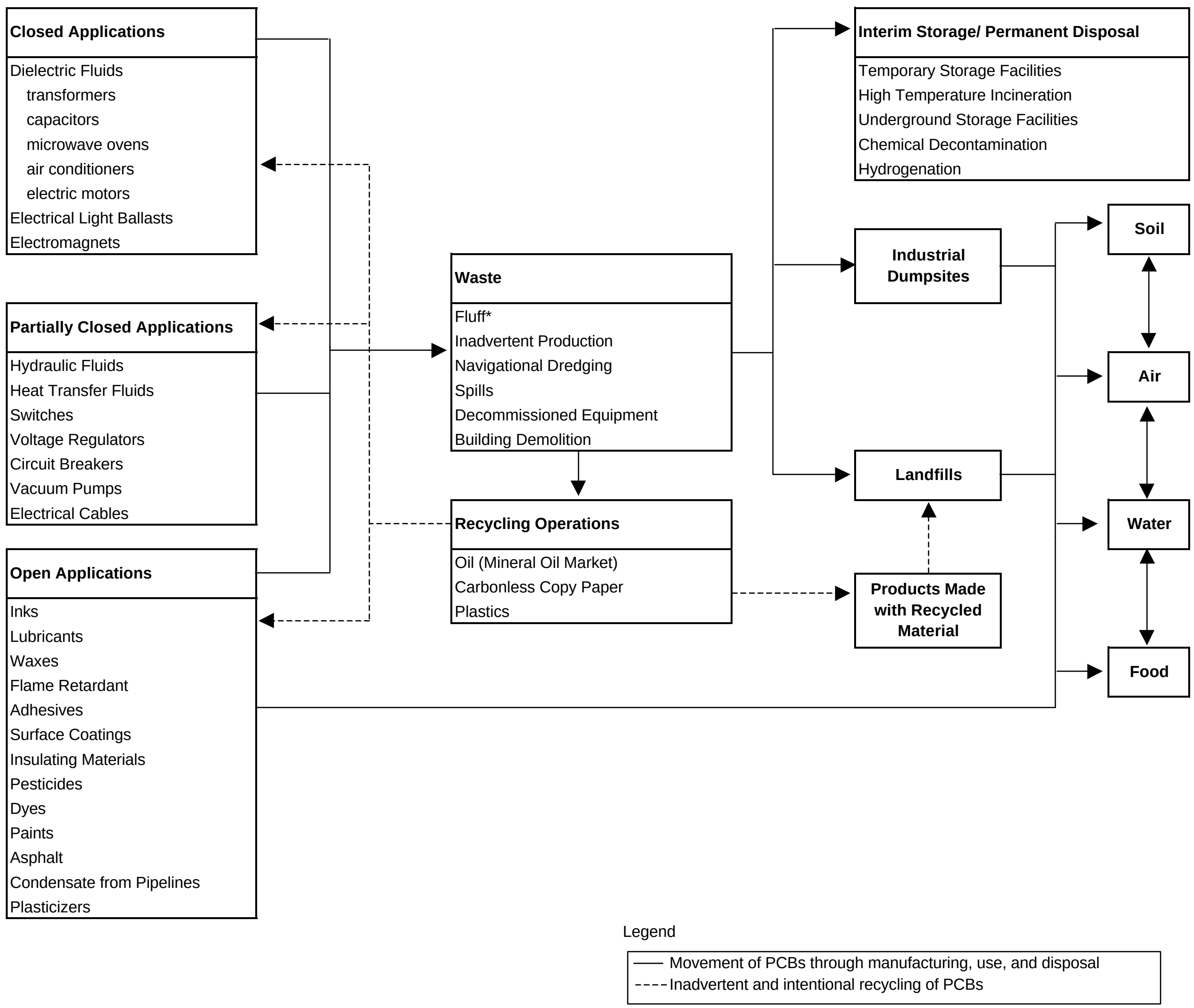
- Section 4 Tests for Determining the Presence and Concentration of PCBs
- Annex B Sources of Additional Information

Step 8. Determine the country specific and environmentally responsible options for permanent or interim storage of the discovered PCB-containing materials. Consult:

- Section 5 Interim Storage and Permanent Disposal
- Annex B Sources of Additional Information

Figure 2 represents the various persistent cycles and pathways that led to widespread distribution of PCBs in the environment. This figure may be a useful tool in the identification of specific focal areas for management or clean-up of PCBs.

Figure 2: PCB Movement in the Environment



* Fluff is waste in the form of upholstery, padding, and insulation materials produced from the shredding of appliances and automobiles that become saturated with PCB-containing oils and fluids.

3.1 PCB Uses

PCBs have been employed in a multitude of applications, many of which are still in use today, including dielectric fluids in electrical equipment, heat-transfer fluids in mechanical operations, plasticizers, lubricants, inks, and surface coatings. The subsections below identify and discuss PCB use areas based on their presence in closed, partially closed, and open systems. These designations refer to how easily the PCBs contained within a product can escape to the surrounding environment (i.e., PCBs in closed systems cannot readily escape to the environment). Generally, closed and partially closed systems contain PCB oils or fluids. The PCBs in open systems take on the form (type of media) of the product they have been used in as an ingredient. Therefore, PCBs in open applications may be found in forms ranging from paint, to plastic, to rubber.

It is often useful to know the source of PCB materials used in various applications. Although trade names for PCB mixtures are not specific to applications, the inclusion of a particular mixture may help to identify useful information for management of PCBs or PCB-containing materials. Trade names for PCB mixtures will most likely only be useful for identification purposes with closed and partially closed applications where equipment labels and manufacturer literature provides information on PCB mixtures. Annex A, Table A.4 provides a comprehensive list of PCB mixture trade names. In the case of open applications, most often the containers that held the original mixtures have been discarded. Thus, in the absence of labels and written indications, open applications often need to be tested for PCB presence (see Section 4).

3.1.1 CLOSED APPLICATIONS

A closed PCB application is one in which the PCBs are held completely within the equipment. Under ordinary circumstances, no PCBs would be available for exposure to the user or the environment. However, PCB emissions may occur during equipment servicing/repairing and decommissioning, or as a result of damaged equipment. The two most significant examples of closed PCB-applications are capacitors and transformers. Table 1 provides examples of closed PCB applications.

In general, it is often difficult to determine the presence of PCBs in sealed equipment, since breaking open the equipment to ascertain this information will usually be inappropriate. Consequently, the first step should always be to refer to maintenance records, manufacturers' literature, trade associations, and equipment manufacturing companies to find information on dielectric fluids contained in the product. Equipment should at a minimum be inspected for any indications of leaks, such as oil stains near the equipment, seepage marks on the equipment, or gross physical damage. These are signs that the equipment needs to be analytically tested for PCBs and repaired or possibly replaced. Following are useful details for identifying PCB-contamination in electrical applications.

Table 1. Closed Applications of PCBs

Electrical transformers
Electrical Capacitors
• *Power factor capacitors in electrical distribution systems*
• *Lighting ballasts*
• *Motor start capacitors in refrigerators, heating systems, air conditioners, hair dryers, water well motors, etc.*
• *Capacitors in electronic equipment including television sets and microwave ovens*
Electrical motors (minor usage in some specialized fluid cooled motors)
Electric magnets (minor usage in some fluid cooled separating magnets)

Sources: Neumeier 1998; US EPA 1994; ICF 1989b.

Transformers. The transformer is a very important component in many different types of electrical circuits, from small-signal electronic circuits to high-voltage power transmission systems. The physical size and shape of transformers vary greatly, from not much bigger than a pea up to the size of a small house. The main structure of a transformer consists of one or more electrical coils (or windings) linked together magnetically by a magnetic circuit or core. For most large transformers, the entire unit is filled with a dielectric fluid (often an oil possibly containing PCBs) to increase the insulation between and to cool the electric coils. Thus, any damage to the transformer's outer casing may result in PCB-fluid leakage. It is important to note that although mineral oil transformers do not intentionally contain PCBs, they often become contaminated by the use of common filling equipment or maintenance filling with used or recycled oil.

Distribution transformers are commonly found near the top of electric utility poles where they function to lower the voltage on the distribution line for household use. Synthetic PCB-oils are commonly used where fire resistant transformers are required, as inside buildings and in nuclear power plants. Transformers are also found in many communication circuits where they function to match a load to a line for improved power transfer and to improve transmission quality. Most transformers are within the control of the electricity generating and distributive companies, although some industries privately generate electricity. These industries, such as military installations, steel mills, assembly and manufacturing plants, and railroads, often have transformers on site. Annex A, Tables A.1, A.2, and A.4 provide additional PCB-containing transformer identification information, including common locations, a list of company names that manufactured PCB-containing transformers, equipment type designations, and PCB mixture trade names.

Capacitors. A capacitor is a device for accumulating and holding a charge of electricity. The main structure of a capacitor consists of electrical conducting surfaces separated by a dielectric material, frequently a dielectric fluid that may or may not contain PCBs. Typically, a capacitor that contains PCBs is a completely sealed metal can with two electrical leads or contacts. The entire can is usually filled with the PCB-containing fluid. Identifying capacitors containing PCB dielectric fluids may be complicated because capacitors are often difficult to locate. They are usually plain boxes that can be remote from switch rooms or found on individual items within a building. Following are descriptions of three major types/uses of capacitors that may contain PCBs. In addition, Annex A, Tables A.1, A.3, and A.4 provide PCB-containing capacitor identification information, including common locations, a list of company and product names, equipment type designations, production dates, and PCB mixture trade names.

- Power Factor Correction Capacitors. Power factor correction capacitors are large capacitors that are generally of uniform size (60 cm x 30 cm x 15 cm) and may contain about 1.4 kg of 100% PCB fluid. Power factor correction capacitors are usually located near transformers, often in racks at power stations. Potential facilities containing capacitors include factories, offices, schools, hospitals, stores, and military installations. Large capacitors would likely be found near sizable power supply units within these facilities (e.g., computer equipment rooms, and central heating and cooling systems).

- Motor Start Capacitors. Motor start capacitors are small capacitors that are used with single-phase motors to provide starting torque. The capacitors can be found in electrical appliances including hair dryers, washing machines, clothes dryers, down-well water pumps, ventilating fans, and air conditioners. These small capacitors generally contain less than 1.4 kg of dielectric fluid.

- Light Ballasts. Lighting ballasts can be found within fluorescent, mercury, and sodium lighting fixtures, and neon lights. Ballasts are composed of a small transformer, a capacitor, and a thermal cut-off switch. The capacitor is the only component that may contain PCBs, typically approximately 0.1 kg of PCB fluid. In fluorescent lights, the ballast is located under the metal cover plate that is behind the lighting tubes (lamps). Ballasts manufactured in the US after 1978 are labeled "No PCBs," and therefore any unlabeled ballast from a US source should be assumed to contain PCBs (US EPA 1993). Annex A, Tables A.1 and A.4 provide additional PCB identification information, including common locations, and PCB mixture trade names.

3.1.2 PARTIALLY CLOSED APPLICATIONS

Partially closed PCB applications are those in which the PCB oil is not directly exposed to the environment, but may become so periodically during typical use. These types of uses may also lead to PCB emissions, through air or water discharge. Examples of partially closed systems include heat transfer and hydraulic systems, and vacuum pumps. Table 2 lists many partially closed uses of PCBs and typical locations.

Table 2. Partially Closed Applications of PCBs

Application	Typical Location(s)
Heat transfer fluids	Inorganic chemical, organic chemical, plastics and synthetics, and petroleum refining industries
Hydraulic fluids	Mining equipment; aluminum, copper, steel, and iron forming industries
Vacuum Pumps	Electronic components manufacture; laboratory, instrument and research applications; and waste water discharge sites
Switches[a]	Electric utilities
Voltage Regulators[a]	Electric utilities
Liquid Filled Electrical Cables[a]	Electric utilities, and private generation facilities (e.g. military installations)
Liquid Filled Circuit Breakers[a]	Electric utilities

[a] These applications were not generally designed to contain PCB materials but may have become contaminated through regular maintenance and servicing.

Sources: Goodwin 1998; US EPA 1994; Dobson and van Esch 1993.

3.1.3 OPEN APPLICATIONS

Open systems are applications in which PCBs are in direct contact with their surroundings and thereby may be easily transferred to the environment. Direct PCB contact with the environment is of greater concern for open uses than it is for closed applications. Plasticizers are the largest group of open applications and are used in PVC (polyvinyl chloride), neoprene, and other chlorinated rubbers. In addition, PCBs have been used in a number of other open uses including in paints as flame-retardants, adhesives as plasticizers, and in surface coatings as flame-retardants. Table 3 lists the common open applications for PCBs.

Table 3. Open Applications of PCBs

Lubricants
• Immersion oils for microscopes (mounting media)
• Brake linings
• Cutting oils
• Lubricating oils
  * Natural gas air compressors
 	
Casting Waxes
• Pattern waxes for investment castings
 	
Surface Coatings
• Paints
  * Paint on the undersides of ships
• Surface treatment for textiles
• Carbonless copy paper (pressure sensitive)
• Flame retardants
  * On ceiling tiles
  * On furniture and walls
• Dust Control
  * Dust binders
  * Asphalt
  * Natural gas pipelines
	Adhesives
	• Special adhesives
	• Adhesives for waterproof wall coatings
	
	Plasticizers
	• Gasket sealers
	• Filling material in joints of concrete
	• PVC (polyvinyl chloride plastics)
	• Rubber seals
	  * Around vents
	  * Around doors and windows
	
	Inks
	• Dyes
	• Printing inks
	
	Other Uses
	• Insulating materials
	• Pesticides[a]

[a] Scrap transformer fluid has been used as an ingredient in pesticide formulas.
Source: Neumeier 1998; Fiedler 1997; Jakobi 1996; Dobson and van Esch 1993.

3.2 PCB-Containing Wastes

Although the manufacture, processing, distribution, and use of PCBs are widely prohibited, there still exist a host of different activities that generate PCB wastes, including: exemptions given to certain uses of PCBs; the incidental production of PCBs; recycling operations; and quantities held within equipment still in service. Annex A, Tables A.1 and A.5 provide additional identification information for PCB-containing wastes, including common locations and sources. Specific examples of activities that generate PCB wastes include:

- PCBs in Used Oil. Because PCBs were widely used in equipment that is still in service today, waste oil collected from this equipment frequently contains detectable PCB concentrations. PCB-contaminated used oil comes principally from industrial and automotive sources and electrical equipment. Industrial sources are typically plants and factories where used oil is used as a fluid in hydraulic and heat transfer systems (Franklin Associates 1984). Used PCB transformer oil has often been mixed with used mineral oil in oil recycling operations, such that low concentrations of PCBs are often found in recycled oil used in trucks and automobiles. Automotive sources are generally gasoline stations and commercial vehicle fleets that collect oil from engine crankcases, transmissions, radiators and other vehicle-related systems. In addition, the condensate in natural gas pipelines can become contaminated with PCBs by contacting PCB containing oils used in the compressors of such pipelines. Users of waste oil should use the tests provided in Section 4 to determine PCB presence and concentration.

- Navigational Dredging of PCB-Contaminated Waters and Sediments. Over the years, large quantities of PCBs have been discharged into aquatic environments including rivers, lakes, and estuarine systems. PCBs tend to adsorb strongly to sediments.[4] Dredging of the bottom to allow ship navigation can therefore generate waste sediments contaminated with PCB levels above 50 ppm (ICF 1989a). PCBs were used in hydraulic fluids in mining equipment and this

[4] The levels of PCBs in water are generally quite low (<1 ng/L) (Environment Canada 1985); however, higher concentrations have been observed near industrial facilities (up to 500 ng/L). In sediments, total PCB concentrations generally fall within the 10 to 2000 µg/kg DW range; however, levels as high as 190,000 mg/kg have been reported in sediments near contaminated sites (Environment Canada 1985).

use was one of the major sources of PCBs that have settled in river water and river sediments (Fiedler 1997).

- Repair and Decommissioning of Equipment. The repair and maintenance of PCB-containing equipment is a source of toxic waste. For example, in the event of a breakdown, transformers are repaired either by the manufacturer or, more often, in repair shops which creates PCB-containing wastes at these locations. Additional significant sources of PCBs may include waste materials generated by cleanup of dielectric fluid leaks at industrial facilities and the explosion or overheating of transformers and capacitors. Furthermore, the decommissioning of PCB-containing equipment may introduce (formerly contained) PCBs into the environment, often in the form of fluff (waste including upholstery, padding and insulation materials derived from the shredding of cars and electrical appliances). Given that transformers and electrical capacitors tend to have relatively long service lives (~ 40 years), the PCBs used in these applications will continue to present a disposal problem well into the next century.

- Building Demolition. In general, large amounts of waste are produced through the demolition of buildings. Of this waste, PCBs are to be found in filling material for joints of concrete structures, flame-retardant coatings on ceiling boards (or tiles), fluorescent light ballasts, coatings on furnishings, surface treatments for textiles, adhesives for waterproof wall coatings, paints, insulating materials, sealant putties, and large and small capacitors (found in appliances and electrical devices).

- Volatilization and Leaching from Landfills. Of the PCBs that have already been disposed, most have likely been deposited in landfills, including municipal, industrial, and sewage sludge landfills. However, PCBs may be released from these landfills by volatilization into the atmosphere and leaching into groundwater. It is likely that much of the PCBs distributed in the waste was originally enclosed in containers, such as capacitors, or was in plasticized resins and will not be released to the environment until the containing medium decays or is damaged. Thus, the diffusion of PCBs from landfills is likely to be slow (Dobson and van Esch 1993).

- Recycling Operations. Through various recycling operations, PCBs have found their way back into the commercial stream. For example, waste paper supplies (carbonless copy paper) may have been recycled into paper and board used as food packaging materials. Another major pathway of PCB environmental exposure is through scrap and waste oil recycling (Jakobi 1996). Additionally, recycled PCB-containing mixtures have been detected in formulations for pesticides and soft soap.

- Incinerators. Emissions of PCBs may occur during the incineration of industrial and municipal waste (e.g., refuse and sewage sludge incinerators). Most municipal incinerators are not effective in destroying PCBs (Dobson and van Esch 1993).[5] It is recommended that destruction of PCB-contaminated waste should be carefully controlled, especially with regard to the burning temperature (above 1100°C), residence time, and turbulence.

- Inadvertent Production by Organic Chemical Manufacturing and Use Industries. There are a number of industrial processes in the organic pigment, pesticide, chemical, and aluminum refining industries that inadvertently produce PCB-laden materials. PCBs can be produced when chlorine, hydrocarbon, and elevated temperatures (or catalysts) are present together (Goodwin 1998). Approximately 90 percent of this production is expected to contain less than 50 ppm of PCBs, and approximately 5 – 10 percent may contain between 50 and 500 ppm of PCBs (ICF 1989a).

3.3 PCB Labeling and Equipment Type Designations

Historically, many large companies designed their own method for PCB identification. The Aroclor series of PCBs manufactured by Monsanto Chemical Company, for example, uses a four-digit code for identification. In the Monsanto codes, the first two digits "12" represent a biphenyl and

[5] PCBs can be converted to polychlorinated dibenzofurans (PCDFs) under pyrolytic conditions (Dobson and van Esch 1993). Thus, the uncontrolled burning of PCBs can be an important source of hazardous emissions.

the last two digits represent the percent of chlorine in the mixture by weight (e.g., Aroclor 1260 is a polychlorinated biphenyl with 60 percent chlorine). Other company codes may represent mean numbers of chlorine atoms in the components (e.g., Clophen A60, Phenoclor DP6, and Kanechlor 600 all are biphenyls averaging about 6 chlorine atoms per molecule) (Dobson and van Esch 1993).

Items that may have PCB classification and concentration labels include: PCB containers, transformers, capacitors, electric motors, hydraulic systems, heat-transfer systems, PCB-article containers, storage areas, and transport vehicles. (Standard PCB labels for the US are square and come in 2.5 cm increments from 5 cm X 5 cm to 15 cm X 15 cm.) For example, US-based items are labeled no-PCBs if they are known to have less than 5 ppm of PCBs. Caution should be used concerning old labels for they may be inaccurate; it may be prudent to re-examine the contents of such items when the equipment is removed from service.

If one is unable to test chemically for PCBs, some of the following assumptions may be appropriate for certain types of electrical equipment. One should assume that all capacitors contain PCBs unless the label or nameplate information, manufacturer's literature, or chemical analysis states that it does not contain PCBs (Goodwin 1998). Similarly, if there is no nameplate on an old transformer and it contains an unknown type of dielectric fluid, then the transformer should be assumed to contain a 500 ppm or greater PCB concentration. If a transformer is known to contain mineral oil dielectric fluid but has no nameplate, then one should assume the transformer contains between 50-499 ppm PCBs.

4. PCB Presence and Concentration Tests

There are a number of analytical tests and detection kits available for determining the presence of PCBs in a material. For example, packed column gas chromatography, thin layer liquid chromatography, and high performance liquid chromatography each can provide information on total PCB levels. Each test provides varying degrees of specificity and resolution. The simple tests listed here will indicate only the possible presence of PCBs, while the detailed analytical tests can generally provide exact and accurate concentration results. Selected PCB test methods are described briefly below.

4.1 Simple Tests for PCBs

The simple tests below can be performed on equipment that has been identified as possibly containing PCBs. These tests are intended for PCB oils in closed and partially closed applications. For open applications, refer to Sections 4.2 and 4.3. The tests described require few materials and can be performed by a non-expert. The tests should be used as a preliminary step because they do not quantify the concentration of PCBs or provide complete verification of PCB presence.

- Density Test. (oil samples) This test compares the density of transformer oil to water to determine PCB presence. By observing if the oil sample floats or sinks, one can determine if PCBs are present – PCBs are heavier than water while mineral oils are lighter than water. Information on this test can be found on the Internet at http://www.tredi.co.nz/html/identify.htm (Tredi New Zealand Limited 1997).
- Chlorine Presence Test. (oil samples) This method checks for the presence of chlorine in transformer oil to determine PCB presence. PCB presence is determined by observing the color of a flame after heating or burning the substance on a copper wire in a gas flame. Chlorine will color the flame green when heated on a copper wire. Since PCB transformer oils contain chlorine while mineral oils (the other typical transformer fluid) do not, this coloration will indicate the presence of PCBs. Information on this test can be found on the Internet at site: http://www.tredi.co.nz/html/identify.htm (Tredi New Zealand Limited 1997; Pombo 1998).

4.2 Detection Kits and Other Instruments

Detection kits are useful when sophisticated laboratory equipment is not easily accessible or when basic screening information is sufficient. These field kits test for the presence of chlorinated organic chemicals, and are not specific for PCBs. Therefore, negative results are useful indications that PCBs are not present, but positive results only indicate that PCBs may be present and confirmation will be required using laboratory procedures. Most of these kits will provide all the needed equipment to perform the tests.

- DR/2010 Portable Datalogging Spectrophotometer. (water samples) This is a portable, water quality analysis tool for fieldwork. On-screen operations can be performed in any of seven languages, including Dutch, English, French, German, Japanese, Portuguese, and Spanish. The spectrophotometer comes preprogrammed with 120 Hach analysis methods. The Internet site to visit for more information is http://www.hach.com. The company may also be reached at:
  Hach Company
  P.O. Box 389
  Loveland, CO 80539-0389 U.S.A.
  Tel: (800) 227-4224 (in the United States)
  Tel: (970) 669-3050 (outside the United States)
  Fax: (970) 669-2932
  Email: csays@hach.com
- Clor-N-Oil. (oil samples) This kit can test transformer oil for PCB presence. This test uses a color change to indicate the presence of chlorine and therefore the likely presence of PCBs. This detection kit can be obtained from the Dexsil Corporation. The Internet site to visit for more information is http://www.dexsil.com. The company may also be reached at:
  Dexsil Corporation
  One Hamden Park Drive
  Hamden, CT 06517 U.S.A.
  Tel: (USA) 1-800-433-9745
  Fax: (USA) 203-248-6523
- L2000 PCB/Chloride Analyzer. (soil and oil samples) This kit tests for PCBs in soil and transformer oils, and is designed to be used in the field to test for PCBs in soil, transformer oil, and on surfaces. The test first reacts the sample with a reagent that strips all chlorine from the organic molecule. Then a chloride specific electrode determines PCB concentration in the reacted sample. The Internet site to visit for more information is http://www.dexsil.com. The company may also be reached at:
  Dexsil Corporation
  One Hamden Park Drive
  Hamden, CT 06517 U.S.A.
  Tel: (USA) 1-800-433-9745
  Fax: (USA) 203-248-6523
- DR/800 Series Colorimeters. (water samples) This is a small colorimeter that can check for PCBs (chloride) in water. It is designed for field use. The Internet site to visit for more information is http://www.hach.com. The company may also be reached at:
  Hach Company
  P.O. Box 389
  Loveland, CO 80539-0389 U.S.A.
  Tel: (800) 227-4224 (in the United States)
  Tel: (970) 669-3050 (outside the United States)
  Fax: (970) 669-2932
  Email: csays@hach.com

- DR/4000 UV-VIS Spectrophotometer. (water samples) This kit can perform water quality analysis. This spectrophotometer allows for both manual and sipper testing. It comes preprogrammed with 130 Hach methods of analysis but it can be programmed to perform other water quality analyses as well. The Internet site to visit for more information is http://www.hach.com. The company may also be reached at:
  Hach Company
  P.O. Box 389
  Loveland, CO 80539-0389 U.S.A.
  Tel: (800) 227-4224 (in the United States)
  Tel: (970) 669-3050 (outside the United States)
  Fax: (970) 669-2932
  Email: csays@hach.com

4.3 Laboratory Analytical Tests

The tests described in this section can provide both actual PCB concentrations and positive verification of PCB presence. The tests require specific testing equipment and materials and should be conducted by persons trained in their use. Some tests can provide only an overall concentration of PCBs while other tests may identify the presence of individual PCB congeners. The document entitled "Verification of PCB Spill Cleanup by Sampling and Analysis" (US EPA 1985) provides documentation on the advantages and disadvantages of many of the tests described below.

- Thin-Layer Chromatography (TLC). (soil and oil samples) This method can be used specifically to test the PCB levels in oils, soils, and in commercial PCB preparations. This method is not always precise, but can produce order-of-magnitude estimates (US EPA 1985; Brinkman et al. 1976; De Vos and Peet 1971; Kawabata 1974; Stahr 1984).
- Gas Chromatography (GC). The GC tests for the presence of organic chemicals in a small amount of oil or volatile solvent such as n-hexane. Transformer oil can be analyzed by being diluted with solvent and then injected into the device. Organic chemicals in soil, solid waste, or water are first extracted (dissolved in the solvent), and the extract is then injected into an inlet port. Organic chemicals in air are first adsorbed on a solid matrix, then desorbed with a solvent and injected. The GC vaporizes the sample and flushes it through a long tube (called a column) that separates the various organic chemicals that are present. As described in the following paragraphs, various detectors at the end of the column generate a signal that is proportional to the amount of each chemical present in the sample. For example, electron capture detectors are sensitive to the presence of chlorinated chemicals, and are usually used for PCB analysis as they do not respond to the non-chlorinated chemicals that may also be present. Mass spectrometer detectors can distinguish among different chemicals that may not be separated by the GC, and are therefore used to analyze samples where many chemicals other than PCBs are present or where it is desirable to analyze for the presence of specific PCB congeners. Detailed information on the various applications of gas chromatography is available in the references cited for each detector system below:
  - Gas-Liquid Chromatography/Electron Capture Detection. (air samples) This method can analyze an air sample for its PCB concentration by passing the air through a material that absorbs PCBs. The absorbed PCBs are subsequently desorbed and the new mixture is analyzed using gas-liquid chromatography with electron capture (Centers for Disease Control 1977). The results are compared to a standard PCB concentration curve (CDC 1977; Boe and Egaas 1979). This method might be used if one is testing indoor air samples, for example in a building in which PCBs may have been spilled.
  - Packed-Column Gas Chromatography/Electron Capture Detection. (spill and transformer oil samples) Packed-column gas chromatography with electron capture detection (GC/ECD) is a sensitive and inexpensive test to operate. This procedure can be used to analyze spill site samples, transformer oils, and other similar media (US EPA 1985; 40 CFR Part 136 Appendix A, Method 608).
  - Capillary Column Gas Chromatography. (solid and liquid samples) This method is used to determine the concentrations of PCBs in solid and aqueous extracts. The capillary columns

can be used with either electron capture detectors or electrolytic conductivity detectors. This method is faster and has better resolution and selectivity than packed-column gas chromatography. This method might be used at a spill site for both soils and water or possibly to test transformer oil or other electrical equipment fluids (US EPA Report Number SW-846, Chapter 4.3.1, method number 8082A.).

- Gas Chromatography/Hall Electrolytic Conductivity Detector. (oil and liquid samples) This method selectively detects PCBs in waste oil, hydraulic fluid, capacitor fluid, and transformer oil. Gas chromatography with Hall electrolytic conductivity detection is less precise than gas chromatography with electron capture detection (US EPA 1985; Webb and McCall 1973; Sawyer 1978).
- Gas Chromatography/Mass Spectrometry. This process performs highly specific identification of PCBs, sometimes even isolating individual PCB isomers. However, this method is generally less sensitive to low levels of PCBs than several of the others mentioned above, is difficult to implement, and is relatively expensive (US EPA 1985; Erickson, et al. 1982; US EPA 1984).
- Thermal Extraction/ Gas Chromatography/Mass Spectrometry (TE/GC/MS). (soils, sludges, and solid samples) This method performs rapid determination of PCBs in soils, sludges, and solid wastes (US EPA Report number SW-846, Chapter 4.3.2, method number 8275A).

5. INTERIM STORAGE AND PERMANENT DISPOSAL

This section provides a brief discussion of various issues relating to PCB storage and disposal. For more detailed information regarding PCB storage and disposal requirements please refer to the additional sources provided in Annex B.

The specific options for PCB disposal will depend on the PCB concentration of the material in question. In some countries, solid wastes (e.g., drained equipment) with high concentrations are required to be deposited in underground facilities with permanent sealing systems (e.g., liners and covers), while liquid wastes may be disposed of through hazardous waste incineration, storage, or hydrogenation.

Many industrialized countries have high temperature incinerators for destroying PCBs and PCB-contaminated wastes (Environment Canada 1985). However, many developing countries have not established such treatment facilities. In these countries, PCBs may be stored pending the establishment of destruction facilities or transport to other countries that have appropriate treatment facilities. The primary method used in Europe and the US for the disposal of liquid PCBs and PCB-containing liquid or solid wastes is high-temperature incineration (> 1100^{o} C). Other techniques for PCB disposal include (Wiesert and Rippen 1997):

- Hydrogenation
- Gasification
- Evapo-incineration
- Underground disposal (facilities with permanent sealing systems)
- Chemical dechlorination (sodium process)
- Electrochemical processing based on silver nitrate
- Plasma arc heating

Especially in the case of developing countries where PCBs are still being disposed of in ways that facilitate their release into the environment (e.g., disposal in unlined landfills), interim storage is considered to be an important step in the process of environmentally sound management. Some fundamental elements to consider include transportation, preparation of containers for shipping, drum labeling, monitoring activities, and storage facilities. It is important to note that all storage installations must be well away from food processing/preparation facilities. For more information regarding PCB management, see Annexes B and C.

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GLOSSARY

Askarel – PCB trade name and also the generic term used for nonflammable insulating liquid in transformers and capacitors.

Ballast – control device found within fluorescent light fixtures and other high intensity lighting fixtures such as mercury, sodium, and neon. It is composed of a small transformer, a small capacitor, and a thermal cut-off switch. The capacitor is the only part that may contain PCBs.

Capacitor – a device for accumulating and holding a charge of electricity. Some were made with PCBs as the dielectric fluid that separates the conducting surfaces.

Closed Application – applications such as capacitors and transformers where the PCBs are in totally sealed containers. PCBs are less likely to escape to the environment from a closed application.

Cutting Oils – a type of cutting fluid used in machining metals to lubricate the tool and workpiece, reducing tool wear, increasing cutting speeds, and decreasing power needs.

Dielectric Fluid – a fluid which essentially does not conduct electricity.

Dissipative Uses – uses in which PCBs are passively released into the environment. This may include various open and partially closed PCB applications.

Fluff – waste including upholstery, padding and insulation materials produced from the shredding of appliances and cars. See Section 3.2 and Table A.5.

Heat Transfer Fluid – an oil used to transport heat or cold between two areas of process-equipment surface, and especially formulated to avoid heat degradation in the temperature range of application.

Hydraulic – operated, moved, or affected by means of water or other fluid.

Hydraulic Fluid – a low viscosity fluid used in operating a hydraulic mechanism.

Lubricating Oil – an oil used to lessen friction between moving surfaces.

Open Application – application in which PCBs are consumed during their use, or are unrecoverable after their use/lifetime of the products. Open applications release PCBs directly into the environment (e.g., plasticizers used in PVC, neoprene, and other chlorinated rubbers).

Partially Closed Application – application in which PCBs are only partially consumed by the use or process. Some of the PCBs are recoverable by the end of the product life. In partially closed applications, PCBs are able to escape to the environment slowly and more indirectly than open applications (e.g., hydraulic fluids, heat transfer fluids).

Polychlorinated Biphenyls (PCBs) – a subset of the synthetic organic chemicals known as chlorinated hydrocarbons and include any chemical substance of the biphenyl molecule that has been chlorinated to varying degrees. The chemical formula for PCBs can be represented as $C_{12}H_{(10-n)}Cl_n$, where n is a number of chlorine atoms within the range of 1-10.

Ppm - parts per million by weight. Unit of concentration of PCBs are also often expressed as milligrams per kilogram (mg/kg).

Transformer - a device that is used to raise and lower voltage. PCB-containing transformers are typically located in electricity generating facilities or buildings.

ANNEX A. STEP-BY-STEP APPROACH FOR PCB IDENTIFICATION

This annex provides a step-by-step approach to PCB identification using several specified guidance tables. Tables beginning with the letter "A" are located in this Annex. All other tables and sections noted are located in the main document. This annex is intended to be used in conjunction with the main document. It is highly advised to carefully read the main document first, especially Sections 3 and 4, and then use this annex as a quick reference tool. The tables provided in this Annex are as follows:

- Table A.1 PCB Applications by Location
- Table A.2 PCB-Containing Transformer Manufacturing Companies
- Table A.3 PCB-Containing Capacitors
- Table A.4 Trade Names and Synonyms for PCB Mixtures
- Table A.5 PCB-Containing Wastes

Step-By-Step PCB Identification

Step 1. Determine possible target locations for PCB inspection. Consult:

- Table A.1 PCB Applications by Location

Step 2. At the target location(s), determine potential PCB-containing applications. Consult:

- Table A.1 PCB Applications by Location
- Section 3 Initial Identification of Potential PCB-Containing Materials

Step 3. For all transformers and capacitors, inspect equipment for initial indication of PCBs. Match equipment with manufacturing companies' information on PCB-containing products. Consult:

- Table A.2 PCB-Containing Transformer Manufacturing Companies
- Table A.3 PCB-Containing Capacitors
- Section 3.1.1 Closed Applications
- Manufacturers' Literature, Maintenance Records, and Trade Associations

Step 4. For other closed and partially closed applications and unclassified transformers and capacitors, inspect for indications of PCB fluid trade names. Consult:

- Table A.4 Trade Names and Synonyms for PCB Mixtures
- Section 3 Initial Identification of Potential PCB-Containing Materials
- Manufacturers' Literature, Maintenance Records, and Trade Associations

Step 5. For potential PCB-containing open applications, consult:

- Table 3 Open Applications of PCBs (page 7 of the main document)
- Section 3.1.3 Open Applications

Step 6. At the target location(s), determine potential PCB-containing wastes. Consult:

- Table A.5 PCB-Containing Wastes
- Section 3.2 PCB-Containing Wastes

Step 7. Test the identified closed, partially closed, and open applications, and wastes for the actual presence and concentration of PCBs. Consult:

- Section 4 Tests for Determining the Presence and Concentration of PCBs
- Annex B Sources of Additional Information

Step 8. Determine the country specific and environmentally responsible options for permanent or interim storage of the discovered PCB-containing materials. Consult:

- Section 5 Interim Storage and Permanent Disposal
- Annex B Sources of Additional Information

Table A.1 PCB Applications by Location

Possible Target Locations[a]	Common PCB-Containing Applications	Reference Tables	Additional Explanation
Electric Utilities (including distribution networks)	Transformers Large Capacitors Small Capacitors Switches Voltage Regulators Liquid Filled Electrical Cables Circuit Breakers Lighting Ballasts	Table A.2 Table A.3 Table A.4	Section 3.1.1 Section 3.1.2 Section 3.3
Industrial Facilities (including aluminum, copper, iron and steel, cement, chemicals, plastics, synthetics, and petroleum refining industries)	Transformers Large Capacitors Small Capacitors Heat Transfer Fluids Hydraulic Fluids (equipment) Voltage Regulators Circuit Breakers Lighting Ballasts	Table A.2 Table A.3 Table A.4 Table A.5	Section 3.1.1 Section 3.1.2 Section 3.3
Railroad Systems	Transformers Large Capacitors Voltage Regulators Circuit Breakers	Table A.2 Table A.3 Table A.4	Section 3.1.1 Section 3.1.2 Section 3.3
Underground Mining Operations	Hydraulic Fluids (equipment) Earthing Coils	Table A.4	Section 3.1.2
Military Installations	Transformers Large Capacitors Small Capacitors Circuit Breakers Voltage Regulators Hydraulic Fluids (equipment)	Table A.2 Table A.3	Section 3.1.1 Section 3.1.2 Section 3.3
Residential/Commercial Buildings (including hospitals, schools, households, offices, and stores)	Small Capacitors (in washing machines, hair dyers, neon tubes, dishwashers, power supply units, etc.) Circuit Breakers Lighting Ballasts	Table A.3 Table A.4	Section 3.1.1 Section 3.1.2 Section 3.3
Research Laboratories	Vacuum Pumps Fluorescent Light Ballasts Small Capacitors Circuit Breakers	Table A.3 Table A.4	Section 3.1.1 Section 3.1.2 Section 3.3

[a] PCB testing of open applications should be conducted at all locations (see Sections 3.1.3 and 4).

Table A.1 PCB Applications by Location (Continued)

Possible Target Locations[a]	Common PCB-Containing Applications	Reference Tables	Additional Explanation
Electronics Manufacturing Plants	Vacuum Pumps Lighting Ballasts Small Capacitors Circuit Breakers	Table A.3 Table A.4 Table A.5	Section 3.1.1 Section 3.1.2 Section 3.3
Waste Water Discharge Facilities	Vacuum Pumps Well Motors	Table A.4 Table A.5	Section 3.1.2 Section 3.2
Automobile Service Stations	Re-Used Oil	Table A.5	Section 3.2
Landfills (including industrial and municipal waste sites)	Decommissioned Equipment Building Demolition Fluff Spills	Table A.5	Section 3.2

[a] PCB testing of open applications should be conducted at all locations (see Sections 3.1.3 and 4).

Notes for Tables A.2 and A.3

PCB Equipment Type Designations: Historically, many large companies designed their own method for PCB identification with assigned number codes on equipment labels. In Tables A.2 and A.3, some company names are followed by information on how to identify specific transformer and capacitor models containing PCBs. This is denoted in the tables as type designation.

Items that may have PCB classification and concentration labels include: transformers, capacitors, electric motors, hydraulic systems, heat-transfer systems, PCB-containers, and storage areas. When inspecting equipment, look for the type designations on name plates, product labels, and in manufacturers' literature. Please see Section 3.3 PCB Labeling and Equipment Type Designations (in the main text) for more details.

Production Dates: The dates provided show only the production period of the product. It is important to consider that products may have been sold well after the production time frame provided. Furthermore, the re-use (recycling) of oils and other PCB-containing substances can lead to contamination of newer products. Additional production date data will be incorporated as it becomes available.

Table A.2 PCB-Containing Transformer Manufacturing Companies

USA	R.E. Uptegraff Mfg. Co.
Westinghouse	H.K. Porter
General Electric Company	Van Tran Electric Co.
Research-Cottrell	Esco Manufacturing Co.
Niagara Transformer Corp.	**GERMANY**
Standard Transformer Co.	AEG (Divisions in Germany)
Helena Corp.	Type designation- The letter C followed by a 3 or 4 digit number stating the power rating.
Hevi-Duty Electric	
Kuhlman Electric Co.	Trafo Union (TU)
Electro Engineering Works	Type designation – The letters TC followed by 4 digits. Some may have the same designations as AEG transformers.

Sources: Dobson and van Esch 1993; Swedish Occupational Health and Safety Board 1985; Durfee 1976.

Table A.3 PCB-Containing Capacitors

Commercial Product Name or Company Name	Production Dates[a]
ASEA and SIEVERTS • Shunt series capacitors; furnace capacitors Type designations: CHA, CHF, CTDA, CKTA, CR, CRS, CPNI, CHX • High frequency capacitors Type designations: CHF-31, CVF-31, CVFA, CTVA, CVGA • Low voltage capacitors Type designations: CLD, CLFA, CRA, CRK, CRKS, CLEO1, CLDO1 • Special capacitors Type designations: CLFL, CRU, CUD, CVH, HMRV	
SIEMENS (Divisions in Germany) • All power capacitors for 50 Hz and rated over 1 kV (year given by first two digits following the letter D of manufacturing number) • Low voltage capacitors Type designations: CO, CD, 4RA, and 4RL	1950-1975
NOKIA • Low voltage capacitors (year given by first two digits in manufacturing number) and: Two letter type designation; or A, D, E, I, O, or U as a third letter in the type designation • High voltage: Two letter type designation; or I, K, O, P, S, U, or V as a third letter in the type designation	1960-1976 1960-1978
SPRAGUE (USA) • Capacitors marked Chlorinol	
AEG or Hydrowerk (Divisions in Germany) • Units with impregnation fluid marked as: Clophen 5 CD, 4 CD, 3 CD	
ACEC • High voltage capacitors Type designation: CAN 50	
NATIONAL INDUSTRY • High voltage capacitors Type designation: FPF-U 2C-20100A03	
GENERAL ELECTRIC (USA) • High voltage capacitors Type designation: UNIFILM 100	
WESTINGHOUSE (USA) • High voltage capacitors Type designation: DV	
LILJEHOLMEN • Low voltage capacitors Type designation: DRA	
AEROVOX (USA)	
UNIVERSAL MANUFACTURING CORP. (USA)	
SPA “CONDENSATOR” (Russian Federation) • Capacitors Type designation: KSK	Through 1988
CORNELL DUBILIER (USA)	
P.R. MALLORY & CO., INC. (USA)	

Commercial Product Name or Company Name	Production Dates[a]
SANGAMO ELECTRIC CO. (USA)	
ELECTRIC UTILITY CO. (USA)	

Table A.3 PCB-Containing Capacitors (Continued)

Commercial Product Name or Company Name	Production Dates[a]
CAPACITOR SPECIALISTS (USA)	
JARD CORP. (USA)	
YORK ELECTRONICS (USA)	
MCGRAW-EDISON (USA)	
RF INTERONICS (USA)	
AXEL ELECTRONIC, INC. (USA)	
TOBE DEUTSCHMANN LABS (USA)	
CINE-CHROME LAB, INC. (USA)	

[a] The dates provided only note the production period of the product. Products may have been sold after the time frame provided and re-use of oils and other PCB-containing substances could have contaminated newer products. Additional production dates will be incorporated as they become available.

Sources: Dobson and van Esch 1993; Swedish Occupational Health and Safety Board 1985; Durfee 1976.

Note for Table A.4

Table A.4 provides an alphabetical list of the many trade names and synonyms commonly given to PCB mixtures. Readers should note that translation or transliteration may account for some of the small variations in otherwise similar names shown in the table. Additionally, trade names for PCB mixtures are usually not specific to applications, but rather can be the name of the PCB mixture used in any application. PCB mixture trade names most likely will only be useful for identification purposes with closed and partially closed applications where equipment labels and manufacturer literature may provide information on the employment of PCB-containing mixtures. In the case of open applications, most often the containers that held the original materials have been discarded. Therefore, all open applications must be tested to determine PCB presence (see Section 4).

Table A.4 Trade Names and Synonyms for PCB Mixtures

Aceclor (t)	Cloresil	Montar
Adkarel	Clorphen (t)	Nepolin
ALC	Delor (Czech Rep.)	Niren
Apirolio (t, c)	Diaclor (t, c)	No-Famol
Aroclor (t, c) (USA)	Dialor (c)	No-Flamol (t, c) (USA)
Aroclor 1016 (t, c)	Disconon (c)	NoFlamol
Aroclor 1221 (t, c)	Dk (t, c)	Nonflammable liquid
Aroclor 1232 (t, c)	Ducanol	Pheneclor
Aroclor 1242 (t, c)	Duconol (c)	Phenoclor (t, c) (France)
Aroclor 1254 (t, c)	Dykanol (t, c) (USA)	Phenochlor
Aroclor 1260 (t, c)	Dyknol	Phenochlor DP6
Aroclor 1262 (t, c)	EEC-18	Plastivar
Aroclor 1268 (t, c)	Electrophenyl T-60	Pydraul (USA)
Areclor (t)	Elemex (t, c)	Pyralene (t, c) (France)
Abestol (t, c)	Eucarel	Pyranol (t, c) (USA)
Arubren	Fenchlor (t, c) (Italy)	Pyrochlor
Asbestol (t, c)	Hexol (Russian Federation)	Pyroclor (t) (USA)
ASK	Hivar (c)	Saf-T-Kuhl (t, c)
Askarel[a] (t, c) (USA)	Hydol (t, c)	Saft-Kuhl
Bakola	Hydrol	Santotherm (Japan)
Bakola 131 (t, c)	Hyvol	Santotherm FR
Biclor (c)	Inclor	Santoterm
Chlorextol (t)	Inerteen (t, c)	Santovac
Chlorinated Diphenyl	Kanechlor (KC) (t, c) (Japan)	Santovac 1
Chlorinol (USA)	Kaneclor	Santovac2
Chlorobiphenyl	Kaneclor 400	Siclonyl (c)
Clophen (t, c) (Germany)	Kaneclor 500	Solvol (t, c) (Russian Federation)
Clophen-A30	Keneclor	Sovol
Clophen-A50	Kennechlor	Sovtol (Russian Federation)
Clophen-A60	Leromoll	Therminol (USA)
Clophen Apirorlio	Magvar	Therminol FR
	MCS 1489	

t = transformer
c = capacitor

[a] Askarel is also the generic term used for nonflammable insulating liquid in transformers and capacitors.

Sources: Fiedler 1997; US EPA 1994; Dobson and van Esch 1993; Swedish Occupational Health and Safety Board 1985; Environment Canada 1985.

Note for Table A.5

PCB-containing wastes can be found in numerous locations and as a result of many different activities. Table A.5 pairs activities and sources of PCB wastes with locations in which one would most likely find those wastes. One can use this table to trace the existence of PCB-waste back to its original source activity or to predict where PCB waste may be found as a result of a specific PCB-producing activity. For further explanation, see Section 3.2 PCB-Containing Wastes.

Table A.5 PCB-Containing Wastes

Activity / Sources	**Typical Locations**
Fluff[a]	Landfills (Municipal and Industrial)
Inadvertent Production by Chemical Plants	Industrial Waste Disposal Sites Industrial Waste Water Streams
Navigational Dredging	Dredged Water Bodies and Their Sediments
Transfer Spillage[b]	Soil or Water near Landfills and Industrial Sites and along the Roads between Locations
Accidents/Fires	Power Distribution Networks (e.g., transformers) Industrial Sites Materials from Burnt Buildings
Vacuum Pump Cooling Water or Condensate	Water Discharge Sites and leakage
Floor and Equipment Clean-Up Wastes	Landfills Industrial Dump Sites
Repair or Decommissioning of Equipment	Repair Shop Grounds Waste Disposal Sites Equipment repair or decommissioning Sites Industrial Facility Grounds
Building Demolition	Landfills Waste Disposal Sites
Various Recycling Operations Reused Oil Practices	Recycled Oil in Equipment Industrial Plants Pesticide Formulations Soft Soap Formulations Natural Gas Pipelines (from compressors) Automobile Service Stations

[a] Waste (upholstery, padding, and insulation material) derived from the shredding of cars and appliances.

[b] PCB leakage that may take place during the transfer of PCB-containing waste from one location to another.

Sources: Dobson and van Esch 1993; Durfee 1976; Franklin Associates 1984; ICF 1989a.

ANNEX B. SOURCES OF ADDITIONAL INFORMATION

Websites and Organizations

United States Environmental Protection Agency: http://www.epa.gov/

- http://www.epa.gov/pcb - US EPA's PCB Home Page: Can find regulation information to interpretive guidance on how to handle PCBs. The "PCB Q & A Manual" can be found there.

UNEP Chemicals: http://www.chem.unep/ch

- http://www.chem.unep.ch/pops – UNEP Chemicals POPs home page: Has links to sites with POPs references and information on international POPs meetings and events.
- http://irptc.unep.ch/pops/actplan.html – This site has links to some of the sources used to write this guidance document and the accompanying compendium.

Lawrence Livermore National Laboratory: http://www.llnl.gov/

- http://www.llnl.gov/es_and_h/guidelines/pcb/pcb.html - A Lawrence Livermore National Laboratory Environmental Guidelines Document. This document provides guidance on identifying, labeling, handling, and disposing of PCBs; responding to PCB spills; and, keeping records on PCBs and PCB-containing materials.

Tredi New Zealand Limited: http://www.tredi.co.nz

- http://www.tredi.co.nz/html/pcb.htm - PCB home page for Tredi New Zealand.
- http://www.tredi.co.nz/html/identify.htm – Information on the identification of PCBs, including some simple tests. ("Identification of PCBs")
- http://www.tredi.co.nz/html/manage.htm – Information on the management of PCBs, including maintenance and storage information. ("Management of PCBs")
- http://www.tredi.co.nz/html/info.htm – Background on PCBs as well as emergency, spill and fire preparedness information. ("General Information on PCBs")

Agency for Toxic Substances and Disease Registry (ATSDR): http://atsdr1.atsdr.cdc.gov:8080

- http://atsdr1.atsdr.cdc.gov:8080/tfacts17.html - "Polychlorinated Biphenyls" Agency for Toxic Substances and Disease Registry (ATSDR) Tox FAQs. This site explains common questions about the health effects of PCBs.
- http://atsdr1.atsdr.cdc.gov:8080/ToxProfiles/phs8821.html - "PCBs" Agency for Toxic Substances and Disease Registry. Discusses general information about public health and PCBs.

International Centre for Commercial Law: http://www.icclaw.com

- http://www.icclaw.com/devs/uk/ev/ukev_018.htm - "Directive and Action Plan on PCBs Issued" International Centre for Commercial Law. Short overview of the 1996 EC directive on PCBs, which required inventories of PCB-containing equipment and plans for their disposal..

Hach: http://www.hach.com The Hach web site. This site contains information on available PCB test kits.

- http://www.hach.com/Spec/SDR2010.htm. The Portable Datalogging Spectrophotometer
- http://www.hach.com/Spec/SDr4000.htm. The UV-VIS Spectrophotometer
- http://www.hach.com/Spec/SDR800.htm. The DR/800 Series Colorimeters

The Dexsil Corporation: http://www.dexsil.com

- The Dexsil Corp. web site. This site contains information on available PCB test kits.
    - http://www.dexsil.com/clor-n-o.htm. The Clor-N-Oil test kit.
    - http://www.dexsil.com/12000web.htm. The L200 PCB/Chloride Analyzer

Occupational Safety and Health Administration, U.S. Department of Labor: http://www.osha.gov

United Kingdom Department of the Environment: http://www.environment-agency.gov.uk/

Environment Canada (Canadian Department of the Environment): http://www.doe.ca/

http://www.hazmatmag.com/library/PCBRegs96/PCBRegs96e.html
- "PCB Waste Export Regulations, 1996." This site describes the regulatory impact of PCB waste export regulations (of the Canadian Environmental Protection Act) on Canada, and on Canadian and American industries and government.

http://128.174.5.51/denix/Public/Library/FGS/Japan/14_pcbs.html
- This site provides information on Japanese PCB regulations.

http://www.cbsc.org/ontario/bis/2369.html
- Canadian restrictions on the Manufacture, Use, Import and Export of Electrical Equipment Filled with PCBs. This information comes from the Canadian Environmental Protection Act, R.S.C. 1985, c. 16, 4th Supplement. The name of the relevant regulation is Chlorobiphenyls Regulations, SOR/90-152. The information applies to manufacturers, processors, users, and importers of electrical equipment filled with PCBs.

http://www.lehigh.edu/kaf3/public/www-data/background/pcbs.html
- Ken Friedman's Home Page, Chemical Backgrounder: PCBs: Once widely used as dielectric coolants and lubricants in industrial equipment, polychlorinated biphenyls have been found to be accumulating in the environment at levels that may affect the health of wildlife and humans.

http://www.state.nh.us/des/ard-15.htm
- Cleaning Up PCB Spills From Small Capacitors
- EPA's PCB Spill Cleanup Policy

http://www.os.dhhs.gov/progorg/sais/lognet/log_man/10342110.HTM#103-42.1102-2
- "Special Types of Hazardous Materials and Certain Categories of Property." This site provides classification information.

ANNEX C. COMPENDIUM OF RELEVANT DOCUMENTS

This annex provides brief summaries of documents related to polychlorinated biphenyl (PCB) management plans or other areas of interest regarding PCBs. The summaries point out specific sections of the documents that provide relevant information on PCB management or other useful information. Also, the full bibliography of each document is provided. Documents may be obtained by request from UNEP through e-mail at POPS@UNEP.ch or through fax at +41 22 797 34 60.

It should be noted that this compendium is considered to be a work in progress. The examples and information presented in this report were drawn from documents available to UNEP Chemicals and other sources that are currently accessible through library and Internet search engines. Additional information will be incorporated as it becomes available. Below is a list of the documents presently included in the compendium. The language of the original document is noted in parenthesis following the title of the document.

Management Documents

I. International Experts Meeting on Persistent Organic Pollutants Towards Global Action (English)

II. Management of PCBs in the United States (English)

III. Management of PCBs in North America (English)

IV. The PCB Regional (North American) Action Plan (English)

V. United Kingdom Action Plan for the Phasing Out and Destruction of PCBs and Dangerous PCB Substitutes (English)

VI. Pilot Project for the Environmentally Sound Management of PCBs in Cote D'Ivoire (French)

VII. Canadian PCB Waste Export Regulations of 1996 (English)

VIII. Oslo-Paris Convention (German)

IX. The Management and Disposal of PCBs in Canada (English)

X. PCB in DDR – Haushaltsgrossgeraten (PCB in East German Large Household Appliances) (German)

Informational Documents

XI. PCB Overview (English)

XII. PCB Question and Answer Document (English)

XIII. The Technical Life-Cycle of PCBs (Case Study for Germany) (English)

XIV. Persistent Organic Pollutants (POPs): Recent Developments in the Intergovernmental Forum on Chemical Safety (IFCS) (English)

XV. Scrap Metal Shredding and Overview of PCB-contaminated Fluff (English)

XVI. PCB Spill Clean-Up by Sampling and Analysis (English)

XVII. Sewage Sludge Use in the Federal Republic of Germany (English)

XVIII. Substitutes for PCBs Used in Capacitors, Transformers and as Hydraulic Fluid in Underground Mining (English)

XIX. PCB I Norge – Forekomst og forslag til tiltak (The Extent and Use of PCBs for Proposals and Measures for Collection and Disposal) (Norwegian)

Compendium

I. Environment Canada. Prepared for International Experts Meeting on Persistent Organic Pollutants Towards Global Action, Vancouver, Canada, June 1985; Meeting Background Report, Vol. IV.

This document is a source of information on persistent organic pollutants. One section of the document focuses on PCB related issues, including: history, human health and toxicological effects, trade name information, persistence, fate and bioavailability, bioaccumulation, production, import/export, uses, releases, and disposal, as well as control actions and alternatives to PCBs.

II. U.S. Environmental Protection Agency (US EPA). *Management of Polychlorinated Biphenyls in the United States,* U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. U.S. Government Printing Office: Washington, D.C., Internet: http://irptc.unep.ch/pops/indxhtms/pcbtoc.html, 1997.

This document provides an overview of the issues surrounding PCBs and PCB management. The materials included discuss products, sources, and releases of PCBs; identification and testing for PCBs; and factors affecting a PCB management program. The PCB identification review is short, but provides assumption rules for identifying PCB contaminated equipment.

III. PCB Task Force. *Management of PCBs in North America*, Commission for Environmental Cooperation: Montreal, Canada, 1997.

This document provides information on progress towards implementation of the North American Regional Action Plan on PCBs (as of 1997). It covers the US, Canada, and Mexico, describing for each country both the steps that have been taken thus far to manage PCBs and the goals that the countries plan to eventually attain.

IV. North American Task Force on PCB. In PCB regional [North American] action plan; *The Sound Management of Chemicals Initiative;* 1996.

The document covers the general topic of effective management of chemicals. The section to be referenced here is the North American regional action plan for the management of PCBs. The action plan covers issues such as pollution prevention, technology transfer, management of use, storage, and waste, and infrastructure necessary to implement the plan.

V. United Kingdom Department of the Environment. *United Kingdom action plan for the phasing out and destruction of polychlorinated biphenyls (PCBs) and dangerous PCB substitutes,* United Kingdom Department of the Environment, 1997.

This document is an overview of the United Kingdom's process for PCB phase-out. The document covers issues relating to equipment, regulations, registration of PCB equipment, identification, and testing.

VI. *Pilot project for the environmentally sound management of PCBs in Cote d'Ivoire*. Secretariat of the Basel Convention, The Ministry of the Environment of Cote d'Ivoire, and the United Nations Environment Programme: 1998.

This document covers five activities undertaken to help develop a national plan for the environmentally sound management of PCBs. The document provides information on national PCB workshops, national inventories of PCBs and PCB equipment, strategies for PCB storage, national regulations, and national plan preparations.

VII. Canadian Department of the Environment. "PCB waste export regulations, 1996: Regulatory Impact, Analysis Statement." Internet: http://www.hazmatmag.com/library/PCBRegs96/PCBRegs96e.html, 1996.

This document discusses in detail the waste export regulations of Canada as well as how the regulations were formulated. It also provides an example of the issues to investigate when considering exporting PCBs for disposal.

VIII. Wiesert, P.; Rippen G. "Uberarbeitung der PARCOM-decision zu polychlorierten biphenylen"; Oslo-Paris Konvention, September 1997.

This document provides information on the decisions of the Oslo-Paris Convention regarding the phasing out of PCBs, hazardous PCB substitutes, evaluation of PCB substitutes, PCB disposal techniques, and PCB substitutes available and currently in use.

IX. Hart, S.; Hilborn, J. Presented at the Subregional Awareness Raising Workshop on Persistent Organic Pollutants (POPs), Kranjska Gora, Slovenia, May 1998; The Management and Disposal of PCBs in Canada.

This short paper walks through the major Canadian regulations regarding PCB management, storage, waste export, and disposal. It discusses the Canadian Council of Ministers for the Environment guidelines specifically. Finally, it discusses disposal and destruction of PCBs in Canada, providing case studies for examples.

X. Jungbluth, N.; Kaspar, R.; Ostermayer, U.; Schmied, M. *PCB in DDR – Haushaltsgrossgeraten*. Technische Universitat Berlin: Berlin, Germany, 1993.

This document is a collection of data on PCB-containing discarded household appliances in East Germany. The data was used to estimate future disposal rates of PCB-charged capacitors found in these household appliances. This paper also discusses the need to collect used PCB-charged appliances separately so that they do not contaminate other household trash and pose a risk to workers at disposal sites. Original document is in German.

XI. Dobson, S.; van Esch, G.J. *Environmental Health Criteria 140: Polychlorinated Biphenyls and Terphenyls,* 2d ed.; World Health Organization, International Programme on Chemical Safety (IPCS): Geneva, Switzerland; 1993.

This is a comprehensive book on PCBs covering in detail aspects from identification and classification of PCBs to the effects of PCBs on organisms in their environment. The sections highlighted here focus on information that will aid identification and testing of materials that may be PCB contaminated.

XII. U.S. Environmental Protection Agency (US EPA). *PCB Q & A Manual,* 1994 ed. Internet: http://www.epa.gov/opptintr/pcb/manual.pdf, 1994.

This is an informal document that covers background on PCBs and information as it relates to specific use areas of PCBs. Applications covered range from transformers to electromagnets. The beginning of each section provides a short synopsis of how PCBs were used in the application being covered and provides tips on sources to check for PCB contamination.

XIII. Neumeier, G. Presented at the Subregional Awareness Raising Workshop on Persistent Organic Pollutants (POPs), Kranjska Gora, Slovenia, May 1998; The technical life-cycle of PCBs.

This short paper provides both a brief background on PCBs as well as a detailed study of Germany's use, production, and disposal of PCBs. This is an excellent case study of a nation that has inventoried PCB information and has passed legislation regulating further use and disposal.

XIV. Buccini, J. Presented at the Subregional Awareness Raising Workshop on Persistent Organic Pollutants (POPs), Kranjska Gora, Slovenia, May 1998; Persistent Organic Pollutants (POPs): Recent Developments in the Intergovernmental Forum on Chemical Safety (IFCS).

This short document provides information on the POPs issue in the international arena. Specifically, it 1) identifies some international initiatives on POPs, 2) provides a summary of the UNEP/IFCS initiative on POPs, and 3) discusses the role of national and international bodies in the effort to control POPs.

XV. ICF. *Scrap Metal Shredding: Industry Profile and Implications of PCB-contaminated Fluff;* U.S. Environmental Protection Agency, U.S. Government Printing Office: Washington, D.C., 1989b.

This document goes into detail regarding the shredding industry and how PCB regulations will affect the industry. The introduction section defines fluff (waste including upholstery, padding, and insulation materials derived from the shredding of cars and appliances), describes how it becomes contaminated and explains why this contamination is a problem.

XVI. U.S. Environmental Protection Agency (US EPA). *Verification of PCB Spill Cleanup by Sampling and Analysis;* U.S. Environmental Protection Agency, Office of Toxic Substances. U.S. Government Printing Office: Washington, D.C., 1985.

This document talks in detail about how to perform verification tests, especially after a PCB spill. The Analytical Techniques section of the document covers testing techniques and specifically compares a number of different types of tests for PCBs. The comparisons point out the major benefits and downfalls of the different procedures.

XVII. Bergs, C.G.; Linder, K.H. Sewage sludge use in the Federal Republic of Germany. *European Water Pollution Control* **1997**, 4(2), 47-52.

This report provides information on why sewage sludge should be tested for organic pollutants (including PCBs).

XVIII. Peter, H.; Jung, S.; Roll, R. Substitutes for polychlorinated biphenyls used in capacitors, transformers, and as hydraulic fluids in underground mining. *Texte* **1993**, 57/93.

This document evaluates a number of possible substitutes for PCBs. It outlines the safety, toxicity, and ecotoxicity tests that the substitutes underwent for each use category (transformers, capacitors, and hydraulic fluids) and then lists which substitutes are safe by these standards. The summary classifies the substitutes as safe, not fully evaluable, and unsafe.

XIX. Statens forurensningstilsyn. 1996. *PCB I Norge – Forekomst og forslag til tilak*. RAPPORT 96:08.

This document summarizes the results of information collection inquiries regarding the use of PCBs in Norway. PCBs were typically used in small capacitors, in grouting, in rubber, in insulated windows, and as additives in concrete. Based on the data collected, designs for PCB collection and disposal systems were proposed