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Inventory of World-wide PCB Destruction Capacity

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IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD

The photo on the cover page is taken from the UNEP/SBC pilot project in Côte d'Ivoire, 1997.

This publication is produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC)

The Inter-Organization Programme for the Sound Management of Chemicals (IOMC), was established in 1995 by UNEP, ILO, FAO, WHO, UNIDO and OECD (Participating Organizations), following recommendations made by the 1992 UN Conference on Environment and Development to strengthen cooperation and increase coordination in the field of chemical safety. In January 1998, UNITAR formally joined the IOMC as a Participating Organization. The purpose of the IOMC is to promote coordination of the policies and activities pursued by the Participating Organizations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

UNEP CHEMICALS

Preface

PCBs are chemical substances which are persistent, bioaccumulate and pose a risk of causing adverse effects to human health and the environment. It is widely accepted that the use of such persistent, bioaccumulating and toxic substances cannot be considered a sustainable practice. However, for different social and economic reasons such substances are still in use and/or released to the environment. With the evidence of long-range transport of these substances to regions where they have never been used or produced and the consequent threats they pose to the environment of the whole globe, the international community has called for urgent global actions to reduce and eliminate releases of these chemicals.

UNEP's Governing 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 UNEP Governing Council also requested UNEP to initiate a number of immediate actions involving development and sharing of information; evaluation and monitoring of the success of implemented strategies; alternatives to POPs; identification of sources of dioxins and furans and aspects of their management; identification and inventories of PCBs; and the worldwide available PCB-destruction capacity;

To promote 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. By the end of 1998, 88 governments had designated 168 such focal points.

Information on available PCB-destruction facilities has been collected from UNEP’s POPs focal points during 1998 and has together with data from other sources, notably from the Secretariat of the Basel Convention (SBC) been incorporated into this inventory of the worldwide capacity to destroy PCBs. The 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.

The inventory has been prepared under contract by the AEA Technology Environment, Culham, Abingdon, OX14 3DB, in the United Kingdom. Any views expressed in the document do not necessarily reflect those of UNEP Chemicals or the Secretariat of the Basel Convention.

UNEP would like to thank donor countries, especially the USA, for their contributions through which the production of this document was made possible. UNEP also thanks government contact points and others who contributed information to the inventory.

This document provides a first attempt to explore the issue of the worldwide capacity to destroy PCBs. Depending on the availability of resources further work will be undertaken to complete and update this inventory and complement it on the wider issue of the environmentally sound management of PCBs.

Klaus Töpfer
Executive Director
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1 Executive Summary

Information on the Worldwide PCB Destruction Capacity has been collected from questionnaires returned by UNEP POPs Focal Points. The questionnaire responses provide a useful body of information on the available facilities in Europe and Asia-Pacific. Few facilities were identified in Africa and Latin America, but a more complete response from these regions may not have identified many more facilities. Facilities in the USA and Canada were identified by the Focal Points to supplement the information in the low number of returned questionnaires. The very limited response from the new independent states of the former Soviet Union may not properly reflect the availability of facilities in that region.

Wastes and waste equipment accepted at the identified facilities are indicated in Tables. Incineration is the commonest method of waste destruction, in either purpose-built hazardous waste incinerators, and, in some countries, in cement kilns. Public acceptance of incineration is not universal and other methods of PCB destruction have started to be established commercially.

A summary of the available technology for treatment of PCB and PCB-containing wastes is included to assist the reader.

On a global scale, the main problem in dealing with remaining waste PCBs and PCB-containing waste equipment is not the availability of technology, or of destruction facility capacity, but of identifying waste inventories (in some countries), and planning and financing their destruction.

2 THE INVENTORY

This Inventory has been prepared for the United Nations Environment Programme (UNEP) with the aim of assisting readers who are involved in the management of certain organochlorine-containing wastes, either directly in the disposal / treatment of identified wastes or in regional waste management planning. The readership will include waste regulators, waste producers, and waste handling and disposal companies. The specific wastes considered are polychlorinated biphenyls (PCBs) and PCB-containing wastes and waste equipment. The Inventory presents information obtained during the study on established facilities for the management of these wastes. Many of these facilities treat, or are capable of treating, a wider range of chlorinated organic substances, and other wastes.

UNEPs̓ involvement in the management of PCB wastes within the Persistent Organic Pollutants (POPs) Programme is described in **Background**. The reasons for the concern over the environmental impacts of PCBs and hence the need to ensure their proper disposal will be well known to many readers, but are summarised for completeness.

The majority of the information on PCB destruction capacity included within the Inventory was collected by means of a **Questionnaire**. The contents of the questionnaire are described in Section 4, as are the processes of information collection by UNEP and information analysis by the contractor.
Decontamination processes for PCB-contaminated equipment and processes for PCB destruction are described in **Sections 5 and 6** to enable the reader to understand the nature of the processes identified in the Inventory. These Sections concentrate on established processes for treatment and destruction of these wastes. In both Sections, the processes are compared to assist readers in judging the suitability of each process for particular wastes. **Section 7** identifies the importance of considering waste storage and transport as part of the management of these wastes.

Worldwide capacity for PCB destruction is described in **Section 8**, which forms the main part of the Inventory, and is based on the responses to the questionnaire. A regional approach has been adopted to assist in the judgement of the availability of particular technology options for identified waste. Contact Points for facilities for which questionnaires were received, and for additional facilities in Germany, Canada and USA, are provided.

The main conclusions from the study are provided in **Section 8**.

A copy of the Questionnaire and a List of Information Sources are provided in **Appendices** together with Technical Guidelines on wastes comprising or containing PCBs, PCTs, and PBBs prepared by the Technical Working Group of the Basel Convention.

3 BACKGROUND

Persistent Organic Pollutants (POPs) are chemical substances which are extremely stable, and are known to accumulate in biological tissue thereby posing a risk of adverse effects to human health and the environment. With the evidence of long-range transport of these substances to regions where they have never been used or produced and the consequent threats they pose to the global environment, the international community has on several occasions called for urgent global actions to reduce and eliminate releases of these chemicals. For example, the UNEP Governing Council, in addressing actions needed on POPs at its nineteenth session in January 1997, concluded that international action is required to reduce the risks to human health and the environment arising from the release of twelve specified POPs, including polychlorinated biphenyls (PCBs). UNEP has initiated a number of immediate actions involving development and sharing of information on the available destruction capacity for POPs, and other issues.

Polychlorinated biphenyls (PCBs) are a class of chlorinated hydrocarbons that have been used extensively since 1930 for a variety of industrial uses. They consist of two benzene rings joined by a carbon-carbon bond, with chlorine atoms substituted on any or all of the remaining 10 carbon atoms. PCBs include mobile oily liquids and hard transparent resins, depending on the degree of substitution. The value of PCBs derives from their chemical inertness, resistance to heat, non-flammability, low vapour pressure and high dielectric constant. As electricity came into widespread use during the first half of this century, equipment suppliers became major users of PCBs. Major applications were as coolants in transformers and dielectrics in capacitors.

The uses of PCBs can be classified as either closed or open. In **closed applications** it was the intention to prevent any loss of PCB by containment within a sealed unit. Contamination of the environment is then consequent upon equipment leaks, for example as a result of a fire. In **open applications** the PCBs are exposed to the environment, and some loss to the environment is inevitable. The major closed applications were as coolants in transformers and dielectrics in capacitors. PCBs were also included in the formulation of a wide range of products including: lubricants, cutting oils, sealing compounds (for the construction industry), adhesives, plastics and rubbers, insecticides, and in paint, varnishes, and other surface coatings including carbonless copying paper.

Between 1929 and 1989, total world production of PCBs (excluding the Soviet Union) was 1.5 million tonnes - an average of about 26,000 tonnes per year. Even after the US banned the manufacture, sale, and distribution of PCBs except in "totally enclosed" systems in 1976, world production continued at 16,000 tonnes per year from 1980-1984 and 10,000 tonnes per year from 1984-1989.

Many of the characteristics that make PCBs ideal for industrial applications create problems when they are released into the environment. The effects on humans and the environment primarily follow chronic exposure. Like many other chlorinated hydrocarbons, PCBs associate with the organic components of soils, sediments, and biological tissues, or with dissolved organic carbon in aquatic systems. PCBs volatilize from water surfaces in spite of their low vapour pressure, and partly as a result of their hydrophobicity. The chemical properties of PCBs favour their long range transport, and PCBs have been detected in arctic air, water and organisms. There is growing evidence linking PCBs and other persistent halogenated aromatic hydrocarbons to reproductive and immunotoxic effects in wildlife. Effects on the liver, skin, immune system, reproductive system, gastrointestinal tract and thyroid gland of laboratory rats have been observed and PCBs are classified as probable humans carcinogens (Group 2A) by the International Agency for Research on Cancer (IARC).

Despite the cessation of production in many countries from the mid 1970s, PCBs continue to be a pollutant of major concern on an international scale. There is still a substantial amount of PCB in use. This results from the long lifetimes of equipment such as transformers, and the exemption given in many countries for contained use, at least for an initial period after imposing a production ban. There are quantities in storage awaiting disposal or at relatively high concentration in soils. Furthermore, there are indications that the production of PCBs has not completely stopped in all countries.

In addition to management programmes undertaken by individual countries and the global POPs convention presently under discussion, a number of international instruments have been developed to control dispersion of PCBs into the environment and to promote the environmentally sound management of PCBs. These include:

North Sea Conference members (Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden, and United Kingdom)	Agreement to phase out and destroy the remaining PCBs in use by 31 December 1999
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989)	Global Legal instrument concerning the environmentally sound management of hazardous wastes, including PCBs, and the control of their transboundary movements. As of 1 December 1998, 121 States and 1 Economic Integration Organization were Contracting Parties to the Basel Convention.
Washington Declaration, Nov 1995 (100 national governments)	Agreement to a Global Programme of Action to phase out POPs, including PCBs
Directive EC96/59 of the European Communities on the elimination of PCBs and PCTs and the phase out by the year 2010	Directive EC/96/59 of the European Council on the elimination of PCBs and PCTs. Aims at harmonizing EU member States legislation concerning the management of PCBs and PCTs in view of their progressive phase out by year 2010.
A new Protocol (1998) on Persistent Organic Pollutants (POPs) to the United Nations Economic Committee for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (LTRAP)	42 countries in the northern hemisphere and the European Community will all be free to sign the POPs Protocol, which covers 16 substances including PCBs. The basic obligations of the Protocol stipulate a wide range of actions ranging from production and use bans and phase-outs, restricted uses and emission controls, and conditions for the disposal of POPs.

Part of the world production has been destroyed, part remains in use or awaits destruction, whilst a substantial proportion has been released to the environment. Depending on the type of waste and the concentration level of PCBs in the wastes, several treatment, decontamination and final disposal options are available. The processes and facilities described in this Inventory apply only to stored equipment and wastes awaiting treatment, and to known equipment still in use. Spillages on land at relatively high concentrations are also candidates for treatment, but PCBs dispersed into the environment are unlikely to be treated (see Sections 5 and 6).

As shown in Section 8 suitable facilities for PCB destruction exist in some countries, but are not universially available. Thus, this Inventory should provide a useful tool for locating suitable facilities. Where suitable facilities are unavailable close to the location of the wastes, the destruction of PCB wastes, including abroad, requires that a number of transportation requirements are taken into consideration. Even when suitable

facilities exist, transboundary transport of PCB wastes may represent the Best Practical Environmental Option (BPEO) if transport distances are reduced and safe conditions for transport are complied to.
Management plans require the development of a waste inventory for the area considered. However, it is not the purpose of this report to discuss inventories, or the details of the planning process. UNEP also plans to produce a separate document on aspects of identifying PCBs and building inventories.

4 THE QUESTIONNAIRE

A questionnaire shown in Appendix A was used to seek information on:

- Location of the PCB-destruction / disposal facility
- Facility type
- Licensing / regulation of facility
- Treatment, disposal & recycling technologies available
- Facility performance
- Types of wastes and waste equipment accepted
- Limitations on waste accepted
- Emissions control and worker protection employed
- Storage of wastes at the facility

In addition, the questionnaire invited the respondents to identify any new initiatives or technology they are planning or researching and to give their opinions on their major concerns and on research and development needs in PCB management.

UNEP circulated the questionnaire to national authorities throughout the world. After receipt, copies of completed responses were forwarded to AEA Technology for analysis. The information obtained was analysed on a regional basis to develop the tabular and graphical summaries provided in Section 8. Some additional information, held by the Secretariat of the Basel Convention has been incorporated into Section 8.

5 DECONTAMINATION PROCESSES FOR PCB-CONTAMINATED EQUIPMENT

Liquid PCBs can be removed from equipment to allow safe disposal or recycle of the solid components. The liquid requires treatment using one of the methods described in Section 6.

Metal components contaminated with PCBs cannot be recycled until the contamination has been first removed. This can be done by solvent extraction or heat treatment, with the PCB waste again treated as described in Section 6. The decontaminated equipment may then be recycled in conventional plant such as metal foundries; for example in Sweden transformers containing less than 500 ppm PCB can be recycled due to co-operation with a scrap dealer. Other contaminated components are treated in a destruction facility. Low boiling point solvents such as propane, butane or hexane can be used to treat soils and sludges. The solvent is recovered for reuse by distillation, leaving the still residues containing PCBs for disposal.

Metal parts are heat treated after loading either on the static hearth of an incinerator or, for smaller parts, into drums to expose the surfaces. Thermal desorption may use either direct or indirect heat exchange to achieve bed temperatures between 170 and 550 ^{o}C, and air or inert gas to transfer vaporised contaminants. The evaporated liquid is condensed and collected for destruction and the decontaminated components can be recycled. Proprietary technology, being operated in Canada by Eco Logic, uses a thermal reduction mill (TRM) to decontaminate soils, and even concrete, with the PCBs then hydro-treated. Draining and solvent washing, described as part of the retrofilling process in the next paragraph, can be used as pre-cursors to heat treatment.

In a process known as retrofilling, PCBs are removed from equipment such as transformers, and the transformer refilled with a substitute oil and returned to service. In this process PCB oil is first drained, then the transformer internals are washed with a solvent such as trichloroethane, and finally the transformer is refilled with new dielectric. Non-trivial amounts of PCB may remain after retrofilling because of the difficulty of washing complex internal parts, especially the windings. The process has to be repeated several times to achieve levels below 50 ppm - the PCB level may be typically 2.5% (25,000 ppm) after one wash. It is difficult to predict the efficiency of the washing process. Retrofilled transformers may have to be operated at a reduced load than formerly, and fire precautions may need to be installed. Given the age of most transformers still containing PCBs, retrofilling is not normally economic, but may be where access to replace a transformer is difficult, for example on oil rigs and in building basements. Retrofilling was identified in only three of the returned questionnaires (France, E10, and United Kingdom, E24 - Table 6; Australia, AP1/2 - Table 9), but is thought to be more widely available as operators can make use of identified destruction facilities.

6 DESTRUCTION PROCESSES FOR PCB WASTES

Destruction of PCBs requires the breaking of molecular bonds by an input of thermal or chemical energy. Biological or radiation energy has been considered but has yet to have a commercial impact. The main features of established processes are summarised in Table 1 and described below. Landfilling is included in this Section, but is essentially long term storage, not destruction. A valuable reference source on technology for PCB wastes is the report on 'Appropriate Technologies for the Treatment of Scheduled Wastes'-Review Report No 4 - November 1997, by CMPS&F - Environment Australia.

Process performance can *inter alia* be characterised by a Destruction Removal Efficiency (DRE) percentage given by

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} \times 100$$

where W_{in} = mass feed rate

and W_{out} = mass emission rate

Table 1 Features of PCB Destruction Processes

Process	Waste types accepted	Advantages	Disadvantages
Incineration examples - rotary kilns, cement kilns	Oils, residues from separation processes PCB-containing waste equipment	High destruction efficiencies achieved, meeting legal requirements, from any of the range of PCBs and waste inputs rendering products safe. Facilities can treat a range of wastes, both chlorinated and non-chlorinated.	PCB content only as a fuel. Costly, especially if wastes have to be shipped off-site. Incineration can attract public opposition.
Chemical dechlorination, and hydrotreating	Liquid PCBs	De-chlorinated oil can be used for other purposes, e.g. lubricating oil.	Need to establish treatment conditions for individual components.
Plasma Arc systems	Liquid PCBs and pumpable solids	Low process inventory.	Limited operational experience of plasma systems for waste treatment

6.1 INCINERATION

The most widely used and proven technology for destroying PCBs is high temperature incineration. Properly done, this has been shown to destroy PCBs at a destruction removal efficiency of at least 99.9999 percent. However, the questionnaire returns report some variability between incinerator facilities in the claimed destruction removal efficiencies, as shown in Table 2.

Table 2 Destruction Removal Efficiency (DRE), % for incineration
No. of units, as reported in Questionnaire

DRE >=	99%	99.9%	99.99%	99.999%	99.9999%	99.99999%
HCl	4	5	1			
PCBs		2	2	2	8	2

The main products of high temperature incineration are carbon dioxide and water, and an inorganic ash. The chloride present is converted to hydrogen chloride gas which is removed, together with other compounds which can be formed as by-products of combustion, using air pollution control equipment. The effectiveness of incineration is a function of residence time, temperature, turbulence and oxygen concentration. Careful process control is required to maintain these parameters at the desired level, and to ensure the effectiveness of the gas cleaning system. The bottom ash produced presents no major disposal problems.

These combustion processes are authorised by their local regulator. The emissions are monitored, several continuously, and the process very carefully controlled to minimise the effect on the environment.

Liquids and dilute slurries are normally pumped into the incinerator. Solid feeds, including equipment for disposal may require some pre-processing of the feed, either by:

- mechanical alteration - for example, shredding to expose contents of capacitors, draining & disassembly of transformers; cutting large transformers to size, or
- packing solids and sludges in drums and feeding via a chute.

Waste handling areas in the vicinity of the furnace entry should be covered and positively drained to a sealed collection sump, with the contents of the sump incinerated.

Incineration may take place in purpose built facilities, designed specifically for PCBs and other chlorinated wastes, or advantage may be taken of facilities developed for the heat treatment of other materials, for example cement kilns, which can be licensed to accept a proportion of chlorinated wastes as fuel. The most important incineration facilities, as identified from the questionnaires, are:

- rotary kiln incinerators (22)
- liquid injection incinerators (6)
- static kiln incinerators (5)
- fluidised bed incinerators (1)
- cement kilns (3)

Rotary kilns consist of a rotating tube inclined at 1 - 2^{o} to the horizontal so that the waste moves horizontally as well as radially through the cylinder. Slow rotation at 0.5 to 2 rpm encourages turbulence. Waste is fed at the high end and ash discharged at the low end. The flue gases pass into a secondary combustion chamber.

Typically for halogenated substances the primary combustion chamber in a rotary kiln operates at a temperature of 1100 ^{o}C (though up to 1300 ^{o}C if the waste demands it), a residence time of at least 2 seconds, and with excess oxygen levels of at least 6% v/v.

Rotary kilns can be run in ‘slagging mode’ producing a fused glassy slag which is low in organics and has a low leaching rate. This mode of operation is understood to be practised in Europe, whereas in the United States these incinerators are operated at temperatures below melt temperatures producing an ash.

Static kilns similarly utilise two-stage combustion on a horizontal grate in the primary chamber. In smaller units, waste is intermittently charged, but the ash is not removed until the quantity interferes with operation. In larger units a ram pushes the charge continually through the incinerator with simultaneous ash removal.

Liquid injection incinerators are refractory-lined cylinders, either horizontal or vertical, equipped with a primary burner for waste and auxiliary fuel to atomise the waste into the combustion chamber. They are suitable for relatively mobile liquid wastes. Some solid contamination is tolerable using an external mix atomiser.

Fluidised-bed incinerators employ a fluidised bed of sand in suspension into which waste is injected as liquid, sludge or uniformly sized solid. Most of the ash remains within the bed, requiring sand cleaning at some point. A number of options for managing the fluidised-bed are possible.

The use of cement kilns represents an example of the disposal of wastes in equipment used for industrial production of commodities. The manufacture of cement requires fuel to heat the aggregate mix, and wastes with a suitable calorific value can be substituted for fuel oil. Waste chlorinated solvents can be fed to the kiln as a fuel supplement. Solid materials can be fed mid-way down the kiln length. A significant advantage of processing chlorinated wastes in cement kiln is that solid residues are incorporated into the clinker product, avoiding the generation of an additional solid waste stream. The HCl reacts in the alkaline atmosphere. Cement kilns have a high degree of thermal stability and provide flame temperatures above 2000 ^{o}C with low retention times for gases and raw materials.

6.2 DECHLORINATION PROCESSES

Dechlorination processes are designed to allow the reuse / recycling of chlorine free oil.

6.2.1 Chemical dechlorination

Chemical dechlorination is based on reactions with either an organically bound alkali metal (sodium naphthalide or sodium polyethylene glycol), or an alkali metal oxide or hydroxide.

Chemical processes are well developed and used commercially to treat liquid PCBs, and PCB contaminated oils. The chlorine content is converted to inorganic salts, which can be removed from the organic fraction, by filtration or centrifugation. Reactions take place under inert atmosphere (to avoid the risk of fire) and in the absence of water (wastes are pre-dried by heating). The plant can be either fixed or mobile, and used on PCB within an operating transformer with the process taking up to a week; a possible disadvantage is that the process may destroy oxidation inhibitors, so limiting recycle of the oil.

The base catalyzed dechlorination (BCD) process can treat wastes containing up to 10% PCBs and reduce chlorinated organics to below 2 ppm. It is a batch process operated in a series of stages:

- addition of alkali as a suspension or dispersion in water, or with a high boiling point solvent (in the range 200 to 500 ^{o}C) at a ratio of between 1 and 20 % by weight
- addition of a hydrogen donor compound - for example the high boiling point solvent, fatty acid or alcohol, and a carbon source such as a carbohydrate
- heating to dehydrate the medium
- heating at a temperature between 200 and 400 ^{o}C for typically 0.5 to 2 hours. The alkali and hydrogen source react, catalysed by the carbon source, to form the hydride ion (H^-) which reacts with the chlorinated hydrocarbon to form a hydrocarbon and the alkali metal chloride

The system is essentially contained and the volume of gaseous emissions is low compared with the combustion processes described above. Capacitors containing PCBs cannot be treated directly as hydrogen is evolved from the contained aluminium under the alkaline conditions. However, this problem can be overcome in a pre-treatment step in which hydrogen is generated and vented at atmospheric pressure.

A process known as PCB Gone has been developed for the in service treatment of transformer oils. Fluid is re-circulated until the PCB concentrations are below those required (typically < 2 ppm). The used fluid is regenerated by filtration through Fullers Earth (to remove acids, sludges and other oxidation products). The process uses a proprietary dechlorinating agent. The Fluidex process offers a treatment process for regeneration of the Fullers Earth, reducing or avoiding the need for its disposal. The PCB Gone process has been introduced by S D Myers in several countries including Australia, England, Canada, Mexico and Saudi Arabia.

6.2.2 Hydrotreating

Hydrotreating is the treatment of oils (i.e. liquid wastes) with high pressure hydrogen gas in the presence of a catalyst. Chlorinated hydrocarbons are broken down to methane and hydrochloric acid, which is converted to a salt solution by scrubbing with caustic soda. A high degree of process control is essential for efficient performance. The water shift reaction and catalytic steam reforming can be used to produce hydrogen from the methane, avoiding the need for an external hydrogen source, but the increased complexity of the overall operation has led to the abandonment of hydrogen recycling in some operations.

6.2.3 Solvated Electron Technology

With the solvated electron technology soils, containing up to 25% water, and metal parts are loaded into a pressure rotating reactor vessel, loaded with liquid ammonia. Alkali or alkaline earth metal, typically calcium, is added which provokes a solvated electron reaction, converting PCBs to hydrocarbons by dechlorination and forming a metal chloride. The ammonia can be recovered for re-use, and the soil can be returned to the site. The treatment of 250 kg batches has been approved by the US EPA.

6.3 PLASMA ARC SYSTEMS

Plasma Arc systems create a thermal plasma field by directing an electric current through a low pressure gas stream for the treatment of chlorinated organic and other wastes. The plasma arc can be used as a heat source for combustion or pyrolysis, or to dissociate the waste into atoms by injecting the waste into the intense high temperature (5,000 to 15,000 ^{o}C) of the plasma arc. PLASCON technology is used to treat liquids and pumpable solids. The very short residence time (20 - 50 milliseconds) means that the process inventory is very low - 0.5 g for the treatment of 1 to 3 tonne waste per day. The electrically powered process can be shut down or started up in seconds. The waste is pyrolysed into ions and atoms at a temperature above 3,000 ^{o}C. These ions and atoms recombine in the cooler area of the reaction chamber prior to a rapid alkaline quench. The end products include gases (argon, carbon dioxide and water) and an aqueous solution of sodium salts. Other plasma systems for treating chlorinated wastes are PACT and STARTECH.

6.4 LANDFILLING

Landfilling is less satisfactory than treatment or disposal methods as the PCB remains a threat, though with proper design and controls a small threat, to the environment. Hazardous waste landfills are designed for containment (entombment) and must meet certain design constraints. Whilst destruction is to be preferred, some PCBs from a range of consumer goods are likely to enter landfills accepting municipal waste. Microbiological action to degrade PCBs is unlikely, especially in the anaerobic environment present throughout most of the active landfill life. PCBs deposited in landfills may therefore contaminate ground and surface waters following migration into leachate. The behaviour of PCBs in landfills is far from fully understood and a precautionary approach is recommended. Deposition with organic materials, e.g. household wastes, will tend to retain the PCBs, but the proximity to organic solvents and oils could enhance levels in leachate. PCB levels in leachate from household waste landfills in the UK were found to contain about 0.05 microgram / litre. This level is not considered a threat to the environment.

Where PCBs are known to be deposited, monitoring of PCB concentrations in leachate should be carried out, both by the landfill operator and regulator. Recommendations on acceptable and unacceptable wastes are available; for example UK guidance identifies the following as wastes which should not be accepted in landfill:

- large quantities of materials such as soil and demolition wastes if they are contaminated by PCB at 50 mg/kg (dry weight basis) or more
- repeated arising of these materials (to exclude large scale disposal in stages)
- transformers that may have contained PCBs
- large capacitors
- small capacitors, if their numbers exceed what would normally be expected in household or similar waste
- contaminated waste oils and dielectric fluids, and other similar liquids, at however low a concentration

Furthermore, UK licence conditions will specify maximum quantity and concentration, by weight, of PCB allowed in the contaminated waste; specify permitted ratio of contaminated waste to biodegradable waste, rarely if ever to exceed 5% of the biodegradable waste input; and require the operator to provide sampling to confirm adequacy of description by waste producers.

7 STORAGE & TRANSPORT

Storage is a necessary element of the management of PCB wastes, but is not a long term option. PCB wastes and PCB contaminated equipment need to be stored under sound (and regulated) conditions before shipment and/or treatment/destruction.

The storage area should be on a firm, impermeable base coated with a suitable sealant and roofed. Areas storing drums and equipment containing PCBs should be bunded. All stored items should be clearly labelled. Several of the plants described by questionnaire respondents store PCB wastes before treatment, but normally with a restriction on the quantities and time of storage permitted. Four examples are:

Plant	**Country**	**Comment**
E6	Finland	Imported waste must be disposed of within 180 days of receipt.
E31	United Kingdom	Material for dismantling, and equipment carcasses are stored for a maximum of six months.
AP5	Australia	Waste (up to 200 tonne) stored on site for between one and six months before treatment.
AP8	China	Waste (up to 300 tonne) stored on site for up to three months before treatment.

As is clear from the discussion below, many countries do not have suitable PCB disposal or treatment facilities. In view of the expense of establishing and operating such facilities, some cross-border transport may be essential if PCB wastes are to be treated in a cost-effective way.

In the case of transboundary movement of PCBs when considered hazardous waste under national law or international agreements, the regulatory regime in force between the countries involved would need to be complied with. Such regimes include that of the Basel Convention, OECD, the European Community, etc. and require a number of legal, technical and administrative measures. PCB and PCB containing equipment when considered wastes are presently being assigned a separate category of the Harmonized Commodity Description and Coding System in countries that are members of the World Customs Organization.

For shipment and transportation of PCBs and PCB containing equipment in general, a number of requirements apply, including labelling and packaging according to the United Nations Committee on the Transport of Dangerous Goods. A Globally Harmonized System for the Hazard Characterization of Products is presently being developed by United Nations organizations and the OECD, which may have effect on requirements for the transportation of PCBs.

8 WORLD-WIDE CAPACITY FOR PCB DESTRUCTION

8.1 INTRODUCTION

This Section summarises the responses to the questionnaire by UNEP Region. The number of responses, including reports that no disposal facilities are available within the country, are shown in Table 3. Maps showing the location of facilities described in the questionnaire responses are presented in Figure 1 – world, and

Table 3 Responses to Questionnaire

Region	Total countries responding	Responses identifying facilities	Number of facilities
Africa	9	2	3
Asia and the Pacific	11	5	12
Europe	17	13	33
Latin America and Caribbean	5	2	3
North America	2	2	2
West Asia	3	2	2

Figure 1 World-wide PCB Destruction Facilities Described in Questionnaires

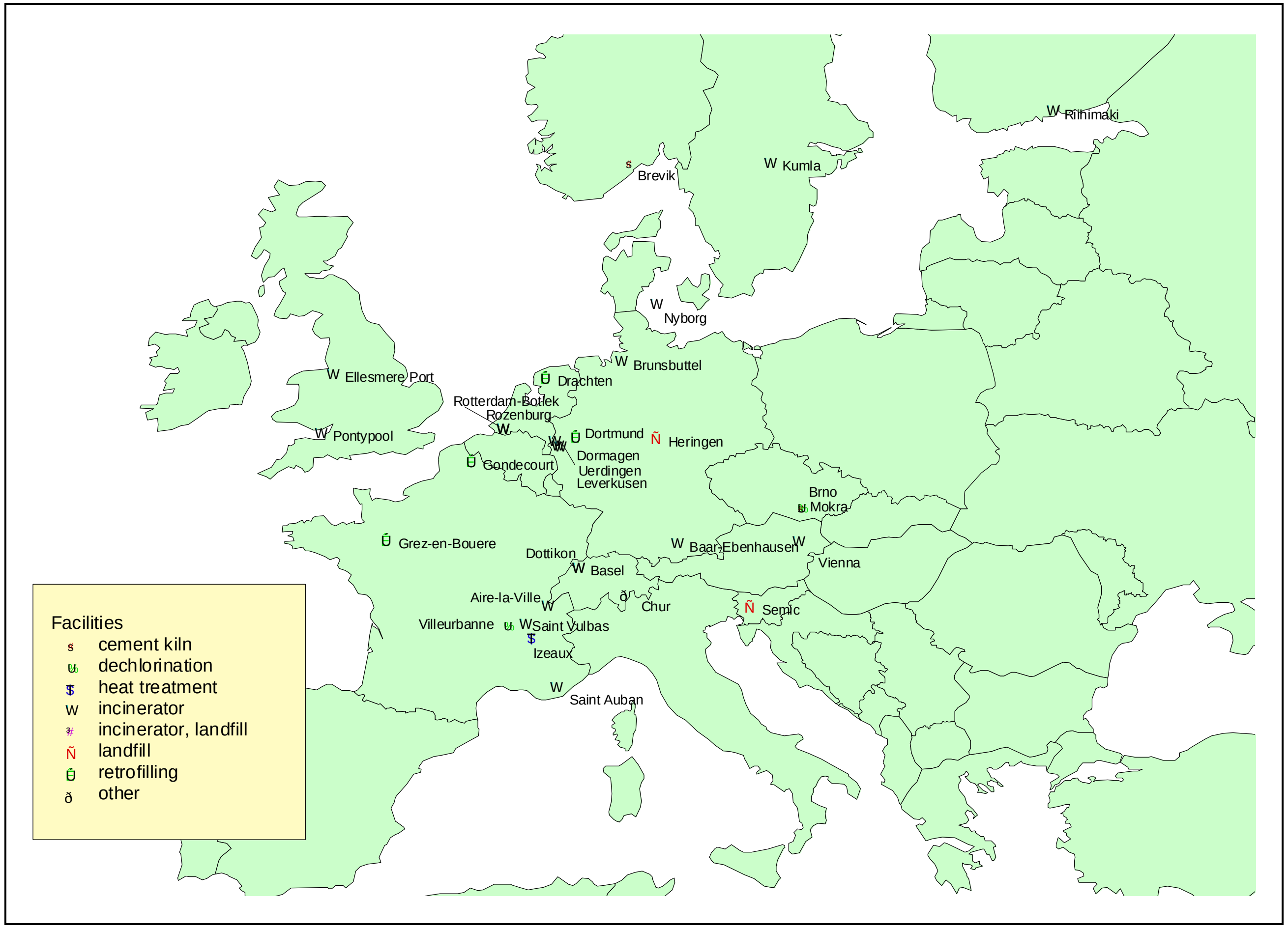

Figure 2 **European PCB Destruction Facilities Described in Questionnaires**

8.2 AFRICA

Very little provision for PCB waste treatment and disposal was identified in the responses.
Nine countries responded of which only the Republic of Cameroon and Rwanda reported on facilities. Their information is summarised in Table 4. Cameroon identified a static kiln incinerator for liquid wastes with a capacity of 220 tonnes, and a landfill for emptied waste equipment. These facilities are Government-operated; in addition privately operated facilities in the Republic of Cameroon were said to have facilities with a high potential for recycling and use different technologies'and include larger than the Government-owned facility, but no other information was provided. Rwanda has a landfill, though it is not licensed to accept PCB wastes.

Table 4 Facilities in Africa

	Country	Facility	Method	Capacity
AF1	Cameroon	Douala/MaKepe Waste Facility c/o Chemicals Management Programme, MINEF/Permanent Secretariat, Yaoundé Centre Tel: 00 237 239231/229482 Fax: 00 237 239461 Dudley Achu Sama National Coordinator Chemicals Management Programme Dual Municipal Waste Facility, Dual, operated by the Chemicals Management Programme	Static kiln incinerator	220 tonne batches handling all incinerable wastes
AF2	Cameroon	Douala/MaKepe Waste Facility, as above	Landfill	For emptied capacitors and transformers
AF3	Rwanda	Nyanza Landfill Ministry of Agriculture, Livestock, Environment & Rural Development, PO Box 621, Kigali Tel: 00 250 85053 Fax: 00 250 85057 Frank Karemera Head of Section - Pollution	Landfill	Apparently for all PCB wastes and equipment

The following countries report no facilities for PCB treatment or disposal:

- Angola
- Burkina Faso
- Lebanon
- Madagascar
- Niger
- Central African Republic
- Togo

One respondent encouraged the development of a local inventory of PCB wastes. This may be a widespread need, and could include other wastes, especially POPs. One Western European respondent identified the absence of information on the quantities of PCB wastes in the developing world. An inventory would identify how the wastes are dispersed, in addition to their total quantity, so guiding the development of waste management plans in the region.

Wastes and equipment accepted at these facilities, and additional services are shown in Table 5.

Table 5 Wastes Accepted and Services Provided at Facilities in Cameroon and Rwanda

Facility	Wastes and equipment accepted											Services offered				
	pure PCBS	PCB-contaminated oils	PCB-containing items / materials	PCB-contaminated residues, sludge	PCB-contaminated soils	packaged / drummed waste		filled transformers	filled capacitors	emptied transformers	emptied capacitors		laboratory analysis / testing	PCB classification / labeling	PCB wastes transport	PCB waste packaging for shipment	clean-up of PCB contaminated sites
AF1		y		y		y									y		
AF2								y	y	y	y				y		
AF3	y	y	y	y	y	y		y	y	y	y				y		y

8.3 EUROPE

There was a good response to the questionnaire from this region, but with some important exceptions. The treatment capacity available, since at least the early 1980s, and the widespread acceptance of incineration as a disposal method has not encouraged the development and implementation of ‘novel’ technologies.

The facilities described in the questionnaire responses are summarised in Table 6. In Germany a number of other facilities were identified by the contact point, and a list of addresses is provided in Table 8.

Landfill facilities were identified at a salt mine in Germany. In Slovenia, a licensed and closed landfill was built for the waste remaining when the Iskra Kondenzaotorji factory at Semic ceased production of electrical equipment containing PCBs in 1985. The waste deposited consisted mainly of polluted soil, but with some condensers and transformers.

The capacities provided in the questionnaires are reported in Table 6 as either total organic waste capacity or PCB waste capacity. These latter figures show a known annual capacity for PCB wastes of 88,000 tonnes, though 30,000 tonnes are accounted for by the facility in Finland. Most facilities are restricted in the amount of chlorine which can be accepted in the waste, and so the 'estimated PCB wastes' column estimates the quantity of PCB waste which could be disposed of at the remaining plants, based on 5% of the total capacity. Including this estimate brings the total PCB wastes destruction capacity figure in Europe to around 111,000 tonnes per annum (tpa) - excluding wastes treated at the six facilities on which capacity information is lacking. The estimated 5% of total capacity is uncertain, as the significant variation in the acceptance criteria, even amongst the German rotary kiln incinerators (E18 to E20) operated by Bayer AG shows. However, this estimated European capacity supports the view of one respondent from The Netherlands that there is sufficient treatment capacity in Europe to dispose of all the world's PCB wastes.

Table 6 PCB Disposal and Treatment Facilities in Europe

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
	Armenia	Ministry of Nature Protection, Republic of Armenia, Moskovyan Str.35, Yerevan 375002 Tel: 00 3742 532801 Fax: 00 3742 151840 Anahit Aleksandryan Head of Hazardous Substances Registration and Control Division	Landfill site, but without an authorisation to accept PCB wastes				
E1	Austria	Entsorgungsbetriebe Simmering GmbH 11 Haidequerstrasse 6 A-1110 Vienna Tel: 0043 1 760 99 502 Fax: 0043 1 760 99 316 Dipl-Ing Jurgen Bode	Rotary kiln incinerator (1980)				nci
E2	Austria	Entsorgungsbetriebe Simmering GmbH, as above	Fluidised bed incinerator (1997)				nci
	Croatia	None	see comment in text				
E3	Czech Republic	CVM Mokrã a.s. 664 04 Mokrã Tel: 00 420 5 44122248 Fax: 00 420 5 44226190 Ing. Zdenek Brzobohaty	Cement kiln – accepting limited quantities of oils containing up to 30 ppm PCBs.				nci

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Technical Director					
E4	Czech Republic	Recetox MU, Kotlarska 2, 611 37 Brno Tel: 00 420 4 41129508 Fax: 00 420 5 41129506 Email: holoubek@chemi.muni.cz Prof. Dr. Ivan Holoubek, Director of Recetox	Dechlorination (BCD)		300		f1
E5	Denmark	Kommunekemi a/s, Lindholmvej 3 – 5800 Nyborg Tel: 00 45 65 31 12 44 Fax; 00 45 65 30 27 63 Jørn Lauridsen Environmental Manager	Rotary kiln incinerator (1989)	50,000		2,500	
E6	Finland	Ekokem Oy Ab, PB 181, Fin-11101, Riihimäki, Tel: 00 358 19 7151 Fax: 00 358 19 715 300 Aarno Kavonius, Director Aarno.Kavonius@ekokem.fi Marku Aaltonen, Marketing Manager Markku.Aaltonen@ekokem.fi	Rotary kiln incinerator (1987/90 - two lines)	40,000	30,000		
E7	France	Aprochim SA Z I La Promenade BP 13	Physico-chemical treatment (solvent extraction) - with capacity of 15,000 tpa - for				

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Grez-en-Bouere 53290 Tel: 00 33 2 43 09 14 50 Fax:00 33 2 43 70 51 89 Philippe Kieffer, Commercial Manager	destruction in facility E12.				
E8	France	Tredi BP 55 Saint Vulbas F-01 151 Lagnieu Cedex Tel: 00 33 4 74 46 22 00 Fax: 00 33 4 74 61 52 44 e-mail: info@tredi.com www.tredi.com	Static kiln incinerator with liquid injection facility (1988)		6,000		
E9	France	Tredi (as E8)	Rotary kiln incinerator (1976)		24,000		
E10	France	Dafeos et Baudassé 61 Rue Decomberousse 69100 Villeurbanne Tel: 00 33 4 72 37 51 60 Fax: 00 33 4 78 26 02 81 Michel Baudassé	Chemical dechlorination (1988) Retrofilling		2,000		
E11	France	GEP Generale D'extraction de Pyralene Le Comptant du Dessus 38140 Izeaux Isere Tel: 00 33 4 76 91 48 66 Fax: 00 33 4 76 91 01 31	Vapour phase extraction from transformers (1988). Collected PCBs (1980 tpa) destroyed by Tredi (E8 & E9).				

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		M. Barbier, Director					
E12	France	Elf Atochem Usine de Saint Auban 04600 Saint Auban Tel: 00 33 4 92 33 75 00 Fax: 00 33 4 92 33 75 61 P Cattet	Liquid injection incinerator (1989)		5,000		
E13	France	Septra Rue Gay Lussac PO Box 13, Gondecourt 53147 Tel: 00 33 3 20 62 92 00 Fax: 00 33 3 20 62 92 01 M Portier	Mobile in-house technology (no details given)				
E14	Germany	Untertage-Deponie, Herfa-Neurode, Heringen, Hessen Hans-Joachim Kind Geschaftsfuhrer Parent Company: Kali und Salz Entsorgungs GmbH, Postfach 102160, D-34021 Kassel, Hessen Tel: 00 49 561 301-1466 Fax: 00 49 561 301-1714	Landfill (salt mine)				nci
E15	Germany	ABB Service GmbH, Kanalstrasse 25, 44147 Dortmund Tel: 00 49 231 9982-000	PCB removal from transformers and condensers				nci

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Tel: 00 49 231 9982-202					
E16	Germany	Entsorgungsbetrieb Ebenhausen, Äusserer Ring 50, 85107 Baar-Ebenhausen, Bayern Tel: 00 49 8453 91-151 Parent Company: Gesellschaft zur Entsorgung von Sondermüll in Bayern mBH (GSB), Winzerer Strasse 47d, 80797 München Tel: 00 49 89 30629-0	Rotary kiln incinerator (1995)	100,000		5,000	
E17	Germany	Bayer AG, Werksdienste Dormagen Umweltschutz, D-41538 Dormagen, Nordrhein-Westfalen Tel: 00 49 2133 515558 Fax: 00 49 2133 515893	Rotary kiln incinerator (1995)	45,000		2,250	
E18	Germany	Bayer AG, Werksdienste Uerdingen, Umweltschutz, D-47829 Uerdingen, Nordrhein-Westfalen Tel: 00 49 2151-887317 Fax: 00 49 2151-7317	Rotary kiln incinerator (1996)	20,000	6,000		
E19	Germany	Bayer AG, Bayerwerk, 51368 Leverkusen, Nordrhein-Westfalen Tel: 00 49 214-30-0-31986	Rotary kiln incinerator (1979)	80,000	2,000		
E20	Germany	Bayer AG, Fährstraße 45, 25541	Liquid injection incinerator	27,000	7,000		

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Brunsbüttel, Schleswig-Holstein Tel: 00 49 4852 81-3447 Fax: 00 49 4852 81-3289					
	Ireland	None	see comment in text				
E21	The Netherlands	Orion BV, De sTeven25, Drachten, Friesland Tel: 00 31 512 532515 Fax: 00 31 512 541130 email: info&orion-pcbs-conversion.nl D Hoogendoorn, Managing Director	Solvent extraction, dismantling and recycling (1990), capacity 8,000 tpa				
E22	The Netherlands	AVR-Chemie, PO Box 1120, Professor Gerbranoyweg 10, Rotterdam-Botlek (3197KK), 3180 AC Rozenburg The Netherlands Tel: 00 31 181 242766 Fax: 31 181 242 502 Ing. A W J Goverde, Marketing Manager International, Ton.goverde@avr.nl	Two rotary kiln incinerators (1986 & 1991)	100,000		5,000	

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
E23	The Netherlands	Akzo Nobel Chemicals, 7020-3000 HA Rotterdam, Welplaatweg 12 - Harbour Nr. 4150, Rotterdam-Botlek, The Netherlands Tel: 00 31 10 4389258 Fax: 00 31 10 4389295 F J Spijk	Liquid injection incinerator (1996) Chlorine Circular Unit	36,000	660		
E24	Norway	Norcem AS, PO Box 38, N-3950 Brevik, Norway Tel: 00 47 35 57 2000 Fax: 00 47 35 57 1400 Tor Faerden, Senior Adviser, Norwegian Pollution Control Authority Tel: 00 47 22 57 36 79	Cement kiln (1980) NOAH, a separate company to Norcem is responsible for collection and pre-treatment of hazardous waste.	31,000	400		f2
	Republic of Belarus	None					
	Romania	TMC, Uzinei St. No. 2, Filiasi, Dolj County Tel: 00 40 051 361270 /361596 Fax: 00 40 051 412300	see comment in text				
E25	Slovenia	Iskra Kondenzaotorji, Vrtaca 1, 8333 Semic Tel: 00 386 68 67 709	Landfill of 10,000 m^3 (1987) - see text				

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Fax: 00 386 68 67 110 Email: iskra.semic@eunet.si Ms Vesna Paun, Ecologist					
E26	Sweden	SAKAB, Box 904, S-69229, Kumla Sweden Tel: 00 46 19 305100 Fax: 00 46 19 577027 Christer Forsgren, Environmental & Technical Manager, christer.forsgren@sakab.se Parent Company: Waste Management International, 3 Shortlands, Hammersmith Int. Centre, London W6 8RX United Kingdom Tel: 044 181 563 7000 Fax: 044 181 563 6300	Rotary kiln incinerator (1979)	40,000		2,000	
E27	Switzerland	ETI Umweltschutztechnik AG, Kalchbuehlstrasse 18, CH - 7007	no details provided				nci

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		Chur Tel: 0041 81 253 54 54 Beat Frey, Swiss Agency for the Environment, Forests and Landscape, CH-3003, Bern Tel: 0041 31 322 69 62 Fax: 0041 31 324 79 78					
E28	Switzerland	EMS-Dottikon AG, CH-6505 Dottikon Tel: 0041 56 616 8111 Fax: 0041 56 616 8120 Beat Frey, see E27	Rotary kiln incinerator	7,500		375	
E29	Switzerland	Novartis Services AG, Waste Management, CH-4002 Basel, Switzerland Tel: 0041 61 696 3420 Fax: 0041 61 468 3348 Beat Frey, see E27	Rotary kiln incinerator (1994)	16,000		800	
E30	Switzerland	Departement de l'interieur et de l'environnement, Route de Verbois, CH-1288 Aire-la-Ville Tel: 0041 22 757 48 20 Beat Frey, see E27	Rotary kiln incinerator	15,000		750	
E31	United Kingdom	Cleanaway Ltd, Bridges Road, Ellesmere Port, Cheshire, CW9	Rotary kiln incinerator (1990)	60,000 (48,000 liquid;		3,000	

No	Country	Facility / Operator / Contact Details including email if known	Method	Destruction Capacity organic wastes, tpa	Destruction Capacity PCB wastes, tpa	Estimated PCB wastes, tpa (f3)	Foot-notes
		6QG Tel: 0044 151 357 3377 Fax: 0044 151 357 3313 Malcolm Gray, Customer Services Manager		12,000 solid)			
E32	United Kingdom	Rechem International Ltd Pontyfelin Industrial Estate New Road, Panteg Pontypool, Gwent NPH 5DQ Tel: 0044 1495 756 231 Fax: 0044 1495 759 019 www.rechem.co.uk Andrew Falconbridge, International Business Manager	Rotary kiln incinerator (1992)	30,000		1,500	
E33	United Kingdom	Rechem International Ltd (as E32)	Static hearth incinerator		5,000		
	Total, tpa			697,500	88,360	23,175	

nci no capacity information provided
f1 based on 1500 kg/day permitted
f2 400 tpa based on 50kg/h permitted
f3 estimated as 5% of organic waste capacity

In France, Tredi Saint-Vulbas (E8 and E9) - part of the state-owned Group EMC, operate a rotary kiln incinerator and a static kiln incinerator for both liquid and solid wastes at Saint-Vulbas. They also operate nine decontamination units for PCB-containing equipment (capacity 16,000 tpa) on this site. The transformers are drained and decontaminated by thermal treatment in autoclaves. The metal components are recycled, the hydrogen chloride produced is converted to hydrochloric acid and the remaining components incinerated. Capacitors are drained, shredded and incinerated. Tredi also have an arrangement with GEP (E11) to incinerate the liquid wastes produced during treatment of transformers.

Also in France, Elf Atochem (E12) and Aprochim (E7) have pooled their resources to deal with chlorinated wastes in transformers and condensers. The liquid wastes are completely stripped from the equipment using the Aprochim solvent extraction process, and the wastes incinerated by Elf Atochem at St Auban.

At the Orion plant in The Netherlands (E21, Table 6) waste equipment is drained and the PCBs flushed out with solvent before dismantling. The decontaminated metals are recycled, the oil recycled and contaminated insulation materials sent for incineration. The Cleanaway facility in the UK (E31, Table 6) offers recycling through retrofilling and solvent extraction. Alternatively, equipment can be dismantled and shredded with the metals (copper and steel) recycled and contaminated material and contaminants incinerated. Also in the UK, Rechem operate a rotary kiln incinerator for liquid and drummed PCB wastes and use a static kiln to decontaminate larger metallic pieces before recycling. The two kilns share the afterburner and gas-cleaning plant.

At Kommunekemi in Denmark, the large transformers are emptied, the liquid incinerated and the emptied transformers disposed of in a salt mine.

In addition to operation of a BCD process, Recetox in the Czech Republic report that they are carrying out laboratory experiments at 70 l / day on sodium dechlorination.

Romania report that they have no facilities for PCB treatment or disposal. Since 1986 when their production ceased, PCB-containing equipment from all over the Country has been stored at TMC, Filiasi (a transformers and capacitor factory). These wastes await recycling, treatment and disposal, but financial support is lacking to enable this to proceed. Armenia have a landfill site, but without an authorisation to accept PCB wastes.

Croatia, Ireland and Republic of Belarus also report no facilities, but do not identify how any PCB wastes are dealt with.

Information on wastes accepted and services provided at European facilities according to the responses is given in Table 7.

Table 7 Wastes Accepted and Services Provided at European Facilities																	
Facility	Wastes and equipment accepted												Services offered				
	pure PCBS	PCB-contaminated oils	PCB-containing items / materials	PCB-contaminated residues, sludges	PCB-contaminated soils	packaged / drummed waste		filled transformers	filled capacitors	emptied transformers	emptied capacitors		laboratory analysis / testing	PCB classification / labeling	PCB wastes transport	PCB waste packaging for shipment	clean-up of PCB contaminated sites
Austria																	
E1/2	y	y	y	y	y	y		y	y	y	y		y				
Czech Republic																	
E3/4		y											y	y		y	
Denmark																	
E5	y	y	y	y	y	y		y	y	y	y						
Finland																	
E6	y	y	y	y	y	y		y	y	y	y		y	y	y	y	y
France																	
E7	y	y	y	y	y			y	y	y	y				y	y	y
E8/9	y	y	y	y	y	y		y	y	y	y		y	y	y	y	y
E10		y	y										y		y		
E11		y	y					y	y	y							
E12	y	y											y				
E13	y	y						y					y	y			
Germany																	
E14			y							y	y						
E15	y	y	y					y	y				y	y	y		
E16	y	y	y	y	y								y		y		
E17									y		y		y	y			
E18		y	y			y											
E19	y	y	y	y	y	y											
E20		y											y				
The Netherlands																	
E21	y	y	y		y	y		y	y	y	y		y	y	y	y	y
E22	y	y	y		y	y		y	y	y	y		y	y	y	y	y
E23	y												y				
Norway																	
E24		y		y	y												
Slovenia																	
E25																	
Sweden																	
E26	y	y	y	y	y	y		y	y	y	y		y			y	y
Switzerland																	
E27	see text																y
E28	y	y	y	y	y	y			y								
E29	see text																
E30	see text																
United Kingdom																	
E31	y	y	y	y	y	y		y	y	y	y		y	y	y	y	y
E32/33	y	y	y	y	y				y	y	y		y	y	y	y	y

For the facilities in Switzerland (Table 6 &7: E27 to E30), a ‘ý’ is indicated in Table 7 only if the box was completed on the questionnaire. However, all four facilities are allowed to accept the same range of special wastes which cover the following categories:

1510 oils which contain PCB or PCT (containing more than 50 ppm PCB)
1511 insulating oils which contain PCB or PCT (containing more than 50 ppm PCB)
3060 appliances and equipment contaminated by PCB or PCT
3061 equipment containing PCB
3062 soil contaminated with PCB
30663 sludges containing PCB

The addresses of several other destruction facilities, and facilities for intermediate storage in Germany were provided with the submitted questionnaires, but completed questionnaires were not provided for analysis in this study. These facilities are listed in Table 8.

Table 8 Facilities in Germany not included in Table 6

Facility Address	Facility Type
Sonderabfallverbrennungsanlage Bergkamen Emst-Schering-Str. 14 59192 Bergkamen Tel: +49 2307 65 730	Hazardous (special) waste incinerator
Sonderabfallverbrennungsanlage Biebesheim Otto-Hahn-Str. 1 64584 Biebesheim am Rhein Tel: +49 6258 809-0	Hazardous (special) waste incinerator
Rückstandsverbrennungsanlage Böhlen, Werkstr. 1 04564 Böhlen Tel: +49 34206 587-0	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage Bramsche Bückowstr. 8-10 49565 Bramsche Tel: +49 5461 9510	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage Brunsbüttel Ostertweute 25541 Brunsbüttel Tel: +49 4852 8308-0	Hazardous (special) waste incinerator
Rückstandsverbrennungsanlage Burghausen Johann-Heß-Str.24 84489 Burghausen Tel: +49 867783 2459	Hazardous waste (residue) incinerator
Rückstandsverbrennungsanlage Frankfurt Werk 343	Hazardous waste (residue) incinerator

Facility Address	Facility Type
Blockfeld E 300 65926 Frankfurt am Main Tel: +49 69 305 5555	
Rückstandsverbrennungsanlage Werk Griesheim Stroofstr. 27 65933 Frankfurt / Main Tel: +49 69/3800-2657	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage der AVG Hamburg Borsigstr.2 22113 Hamburg Tel: +49 40 73351-0	Hazardous (special) waste incinerator
Rohstoffrückgewinnungszentrum Ruhr (RZR) Im Emscherbruch 11 45699 Herten Tel: +49 2366 300-209	Hazardous (special) waste incinerator
Rückstandsverbrennungsanlage Hürth Werk Knapsack Industriestrasse 50354 Hürth Tel: +49 2233 48-6500	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage Ibbenbüren Zepperlinstrasse 49479 Ibbenbüren Tel: +49 5459 56-0	Hazardous (special) waste incinerator
Rückstandsverbrennungsanlage Köln Henry-Ford Strasse 50735 Köln Tel: +49 221 901-4188	Hazardous waste (residue) incinerator
Rückstandsverbrennungsanlage Werk Schlebusch Kalkstr. 218 51377 Leverkusen Tel: +49 214 357-204	Hazardous waste (residue) incinerator
Rückstandsverbrennungsanlage Werk Ludwigshafen Carl-Bosch-Str. 38 67056 Ludwigshafen Tel: 0049 621 60 0	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage Marburg Emil-von-Behring-Str. 76 35041 Marburg Tel: 049 6421 39 2476	Hazardous (special) waste incinerator

Facility Address	Facility Type
Sonderabfallverbrennungsanlage Marl Bau 506 Paul-Baumann-Str. 1 45772 Marl Tel: 0049 2365 49 1, -4674	Hazardous (special) waste incinerator
Rükstandsverbrennungsanlage Müster-Hiltrup Glasuritstr. 1/Postfach 6123* 48165 Müster-Hiltrup/48136 M-H* Tel: 00 49 2501 14 0	Hazardous waste (residue) incinerator
Rükstandsverbrennungsanlage Muldenhütten Flurstük 401/17 09627 Hilbersdorf/Muldenhütten Tel: 0049 3731 367 296 Schnee	Hazardous waste (residue) incinerator
Rükstandsverbrennungsanlage Niederkassel Markusstraße 60 53859 Niederkassel Tel: 0049 2208 4047 48	Hazardous waste (residue) incinerator
Rükstandsverbrennungsanlage Werk Offenbach, Gebäude 257 Mainstr. 169/Postfach 10 08 63* 63075 Offenbach/63008 Offenbach* Tel: 0049 6104 8066 532 Niembs	Hazardous waste (residue) incinerator
Sonderabfallverbrennungsanlage Schöneiche Kreis Zossen Am Galluner Kanal 15806 Schöneiche Tel: 0049 33764 369 or 375	Hazardous (special) waste incinerator
Sondermüllentsorgungsanlage Schwabach Siemensstr. 3-5 91126 Rednitzhembach-Igelsdorf Tel: 0049 9122 797 100 Rükel	Hazardous (special) waste disposal facility
Cablo GmbH Neißstr. 2 35260 Stadtallendorf Tel: 0049 6428 7552 Fax: 0049 6428 5056	Authorised for waste storage, or preparation of transformers / condesnsers
Rolf Märtens GmbH & Co. KG Sondermüll Strotthoffkai 18 28309 Bremen Tel: 0049 421 455095	Authorised for waste storage, or preparation of transformers / condesnsers

Facility Address	Facility Type
Fax: 0049 421 455098	
EES Jürgen Scholz GmbH Transformatorentechnik Oehlecker Ring 6a 22149 Hamburg Tel: 0049 40 5314081 Fax: 0049 40 5315868	Authorised for waste storage, or preparation of transformers / condesnsers
L & Z Entsorgungsdienste für Starkstromanlagen GmbH Am Bubenpfad 2 67065 Ludwigshafen Tel: 00 49 621 5793 0 Fax: 00 49 621 5793 111	Authorised for waste storage, or preparation of transformers / condesnsers
Schorch GmbH Umwelttechnik Rheinstr. 73 41065 Mönchengladbach Tel: 0049 2161 944100 Fax: 0049 2161 944190	Authorised for waste storage, or preparation of transformers / condesnsers
Fred Stemmer GmbH Göttinger Str. 50 34346 Hann. Münden Tel: 0049 5541 72077 Fax: 0049 5541 2717	Authorised for waste storage, or preparation of transformers / condesnsers
Starkstromgerätebau GmbH Ohmstr. 36 93055 Regensburg Tel: 0049 941 7841-0 Fax: 0049 941 71721	Authorised for waste storage, or preparation of transformers / condensers

8.4 ASIA-PACIFIC

The total known capacity in the region is shown as 7475 tpa in Table 9, of which 1070 tpa is for heat treatment and solvent extraction, not destruction. There are a number of recent developments in this region including:

- a rotary kiln incinerator in the Republic of Korea (AP10), which will be the only plant authorised to incinerate PCBs in Korea, is expected to accept wastes from August 1998. Transformers will be drained, solvent cleaned and the steel recycled. This facility is operated by the Waste Treatment Division, Environmental Management Corporation (EMC) a non-profit affiliated body of the Ministry of Environment.
- a cement kiln in Indonesia (AP9) burns PCBs flushed from equipment with diesel until the PCB concentration in the flushing liquid is below 500 ppm; the equipment is then landfilled.
- a new facility in Australia (AP1/2) uses a new perfectly safe method of managing sodium metal, with the oil regenerated using a new reactivatable Fullers Earth Process. Waste is said to account for less than 0.2% of the feed and is sufficiently harmless that it is discharged to the storm water system. Oils containing up to 500 ppm PCBs are collected in a 30,000 litre tanker for treatment. Storage of 90,000 litre is available at the processing facility. The process may be similar to the PCB Gone Process (Section 6.2.1).
- BCD Technologies at Narangba, Australia (AP3/4) have recently added a plasma arc process (PLASCON) to complement their chemical dechlorination facility. The PLASCON unit is used to treat liquid PCBs, which are not ideally suited to the BCD process.
- Haz-Waste in Melbourne (AP6/7) use solvent extraction to treat PCB-containing equipment, with the metal being recycled. The contaminated oil and other wastes are treated by de-chlorination.

Fiji report information on 2 landfills which accept PCB waste and equipment without restriction. At one of these (Lami), PCB wastes are placed in a segregated area of the landfill, and covered with 150 - 200 mm of soil.

The following countries reported that no facilities are available:

- Bangladesh
- Federated States of Micronesia
- Japan
- The Philippines
- Singapore, and
- Thailand

The Federated States of Micronesia are involved in the South Pacific Regional Environmental Programme - Persistent Organic Pollutants (POPs) project. An inventory of persistent organic chemicals is being generated, to be followed by packaging of the collected waste, and waste disposal. Some transformers containing PCBs have been disposed of in landfills. Fiji participate in the Management of Persistent Organic Pollutants in Pacific Island Countries (PICs) Project.

The Secretariat of the Basel Convention report that Japan in 1996 had no thermal treatment facilities available, but other treatment technologies are being developed including chemical dechlorination, supercritical water oxidation process, ultraviolet radiation and biological decomposition.

Table 9 PCB Disposal and Treatment Facilities in Asia-Pacific Region

	Country	Facility	Method	Capacity PCB wastes, tpa	
AP1	Australia	Powerlink, 33 Harold Street, Virginia 4014, Queensland Tel: 00 61 7 3860 2111 Fax: 00 61 7 3860 2100 David Strongman, General Manager	Dechlorination (1997) and retrofilling	430	f1
AP2	Australia	Powerlink, as above	Heat treatment (1997)	570	f1
AP3	Australia	BCD Technologies PTY Ltd, PO Box 119, 2 Krypton Street, Narangba, Queensland Tel: 00 61 7 3202 3405 Fax: 00 61 7 3203 3450 Martin Krynen, General Manager, marius@911.com.au	Plasma arc process (1997)	450	
AP4	Australia	BCD Technologies PTY Ltd, as above	Chemical dechlorination (1991)	2200	
AP5	Australia	ELI Ecologic Australia, Hazardous Waste Destruction Facility, Lot 4 Mason Road, Kwinana 6167, Western Australia Tel: 0061 9 439 2074 Fax: 0061 9 439 2363 ecoadmin@ecologic.com.au Nathan Dixon, Quality Control Manager	Hydrogenation - chemical reduction (1995)	1000	
AP6	Australia	Haz-Waste Services, Jancassco Pty Ltd, PO Box 4012, 101 Ordish Road, Dandenong Sth, Victoria 3164, Australia Tel: 006 13 9706 7966 Fax: 0061 3 9706 5762 K R Carlile, Managing Director	Chemical dechlorination (1994)	250	

	Country	Facility	Method	Capacity PCB wastes, tpa	
AP7	Australia	Haz-Waste Services, see AP6	Solvent extraction (1988)	500	
AP8	China	PCBs Incineration Plant, No. 63 Shashan Street, Heping District, Shengyang 110005 Tel: 0086 24 3316656 Fax: 0086 24 3317668 Shao Chinyan, Senior Engineer	Static kiln and liquid injection incinerator (1995)	300	
	Fiji	Lami Municipal Dump Suva City Council Main Office, Civic Centre, 176 Suva Tel: 00679 313 433 Fax: 00679 302 158 Moti Lal Registrar of Pesticides Ministry of Agriculture Koroniva Research Station Suva Tel: 00679 477 044 Fax: 00679 400 262	Landfill, see text		
	Fiji	Lautoka Municipal Dump Lautoka City Council 169 Vitoco Poc, 124 Lautoka Tel: 00679 660 433 Fax: 00679 663 288 Moti Lal (as above)			
AP9	Indonesia	PT. PPLI, Desa Narbo, Cibinong-Bogor, West Java Tel: 0062 21 823 0307 Fax: 0062 21 823 0308 Syarif Hidayat	Cement kiln (1996)	1575	f2
	Indonesia	PT. PPLI, as above	Landfill (1994) - only if PCB content below 500 ppm		

	Country	Facility	Method	Capacity PCB wastes, tpa	
AP10	Korea	Integrated Waste Treatment Plant, #2 Complex, Kunsan Industrial Estate, Soryong-dong, Kunsan City, Chonbuk Province Tel: 0082 654 467 2285/7 Fax: 0082 654 467 2288 Mr Ho-Jik Kang, Director	Rotary kiln incinerator (due to be commissioned July 1998)	200	f3
Total				7475	

f1 sg of 1.4 assumed in conversion from volume throughput provided
f2 figure for 1% Cl in waste based on limitation to 45 tpa PCB (35% Cl)
f3 based on maximum feed rate of 25 kg/h

Wastes accepted and services provided at facilities in Asia-Pacific Region are summarised in Table 10.

Table 10 Wastes Accepted and Services Provided at Facilities in Asia-Pacific Region

Facility	Wastes and equipment accepted												Services offered				
	pure PCBS	PCB-contaminated oils	PCB-containing items / materials	PCB-contaminated residues, sludge	PCB-contaminated soils	packaged / drummed waste		filled transformers	filled capacitors	emptied transformers	emptied capacitors		laboratory analysis / testing	PCB classification / labeling	PCB wastes transport	PCB waste packaging for shipment	clean-up of PCB contaminated sites
AP1/2		y						y					y		y		
AP3/4	y	y	y	y	y	y		y	y	y	y		y	y	y	y	y
AP5	y	y	y	y				y	y	y	y						
AP6/7	y	y	y	y	y	y		y	y	y	y			y	y	y	y
AP8	y	y	y	y	y	y		y	y	y	y			y	y		
AP9	y	y	y	y	y	y		y	y	y	y		y	y	y		
AP10	y	y	y	y	y	y		y	y	y	y		y	y	y		y

8.5 WEST ASIA

Kuwait identified a facility at Safat, operated by the Environment Public Authority of Kuwait. A rotary kiln incinerator, landfill and chemical dechlorination were all identified on the questionnaire, but no details were provided.

Mauritius identified the Mare Chicone landfill on their questionnaire. Although this is not licensed for PCBs, the response comments that on the information available, PCBs are absent from Mauritius.

Seychelles report no facilities. The contact points for Kuwait and Mauritius are given in Table 11.

Table 11 Contact points for Kuwait and Mauritius

Country	Contact Points
Kuwait	Environment Public Authority 24395 Safat Tel: 00965 48 21 285 –9 Fax: 00965 48 20 570 Raja Al-Busairi, Acting Director General
Mauritius	Ministry of Environment, Ken Lee Tower, Corner St George Street & Barracks Street, Port Louis Tel: 00230 212 3363 Fax: 00230 212 6671 DENVME@Bow-Intnt.Mu Archie Iqbal Technical Officer

8.6 LATIN AMERICA AND CARIBBEAN

Questionnaires describing three facilities were received from Brazil. These facilities are summarised in Table 12, and have a total capacity for PCB wastes of 4200 tpa. The rotary kiln incinerator (LA2) will accept solid wastes and was due to start performance trials in July 1998. CETREL is a privately owned company which was originally intended to treat the liquid and solid waste produced by the Camaçari Petrochemical Complex manufacturing plants, but has evolved to take on a wider role. Since its commissioning in 1992, the company operating the other rotary kiln incinerator in Brazil (LA3) have provided an integrated waste management system which includes a physical-chemical and biological treatment station and a doubly protected industrial landfill.

Chile, Colombia, Paraguay and St Kitts and Nevis report no facilities.

Table 12 PCB Destruction Facilities in Brazil

	Facility	Method	PCB wastes
LA1	CETREL SA Empresa de Protecão Ambiental, Rua Valjenio, s/n Polo Petroquimico de Camaçari, Camaçari, Bahia Fax: 0055 71 832 2389 Email: incinera@catrel.com.br www.cetrel.com.br Armando Goes de Araujo Neto, Head of the Incineration and Hazardous Wastes Area	Liquid injection incinerator (1991)	1200 tpa
LA2	CETREL SA, as above	Rotary kiln incinerator (1998 planned)	500 tpa
LA3	Incinerador Rotativo, Estrada Boa Esperanca, 650 Belford Roxo, Rio de Janeiro Fax: 0055 21 761 4686 Fernando Altina Medeiros Rogrigues, Head of Chemical Environment	Rotary kiln incinerator (1992)	2500 tpa

Table 13 Wastes Accepted and Services Provided at Facilities in Brazil

Facility	Wastes and equipment accepted												Services offered				
	pure PCBS	PCB-contaminated oils	PCB-containing items / materials	PCB-contaminated residues, sludge	PCB-contaminated soils	packaged / drummed waste		filled transformers	filled capacitors	emptied transformers	emptied capacitors		laboratory analysis / testing	PCB classification / labeling	PCB wastes transport	PCB waste packaging for shipment	clean-up of PCB contaminated sites
LA1/2	y	y	y	y	y	y			y		y		y		y	y	y
LA3	y	y	y	y	y	y		y	y	y	y		y				

8.7 NORTH AMERICA

Mexico and Canada completed questionnaires, and the responses are summarised in Table 14 (NA1, NA2, & NA3). The wastes accepted and services provided at these facilities are summarised in Table 15. There are a number of other Canadian companies that provide expertise or have a capability in mobile thermal destruction or chemical dechlorination of contaminated transformer fluids. It has not been possible, at this time, to obtain the detailed questionnaire information for each of these facilities. As of October 1997, the companies listed as NA4 to NA16 in Table 14 provided capabilities for specialised PCB destruction / decontamination in Canada. A list, provided to UNEP, of companies operating facilities for PCB wastes in the USA (NA17 to NA48) has also been included in Table 14, together with limited information on the processes operated. In addition to these 28 permitted commercial PCB disposal companies on this USA list, there also are several other non-commercial permitted companies and several other disposal facilities (high efficiency boilers) which destroy PCBs but which are not required to be permitted.

In Mexico, S D Myers de Mexico operate a 9,000 tpa capacity rotary kiln incinerator which was commissioned in 1998 to treat a range of liquid and solid wastes (NA1 in Table 14). The transformers are decontaminated, and the metal recycled.

The Swan Hills facility in Alberta (NA2) is the only large, PCB destruction facility in Canada which has destroyed PCB wastes from across Canada in a rotary kiln incinerator. All Canadian facilities (including Swan Hills and the several small chemical dechlorination facilities scattered in various provinces) are under provincial jurisdiction. The Swan Hills Treatment Centre is a fully integrated hazardous waste management facility providing comprehensive treatment services. Waste treatment technologies include high temperature treatment (incineration), stabilization and physical/chemical treatment. Non-hazardous solid treatment residues are disposed of in an on-site monitored, secure landfill. Treated liquid effluent is disposed of by deep well injection.

Information from the Secretariat to the Basel Convention is summarised below:

In Mexico:

- S D Myers de Mexico SA de CV at Tlalnepantla recondition transformers by replacing (retrofilling) dielectric fluids contaminated with 50 to 10,000 ppm PCBs. The PCBs are treated by base catalysed dechlorination in a mobile plant.

In Canada:

- ELI Eco Logic in Rockwood, Ontario (NA5) have developed a mobile unit. The SE-25 system has the capacity to treat 20-30 tonne per day of a pure organic waste stream (4000 - 6000 tpa on a 200 day year).

In the USA (1996):

- Chemical dechlorination using alkali reagent is operated in several non-mobile facilities by PPM Inc (NA24), part of Laidlaw Environmental System, Tucker, Ga and in a mobile unit by ENSR Operations Division (NA23), Canton, Ohio.
- Solvated Electron Chemical Dechlorination is operated by Commodore Remediation Technologies (NA22), Inc, Columbus, Ohio (see Section 6.2.3).
- There are approximately 10 commercial PCB incinerators (liquid injection incinerators, rotary kiln incinerators and fluidised beds) - four (NA17 to NA20) identified in Table 14.

Table 14 PCB Disposal and Treatment Facilities in North America

No	Country	Facility	Method	Capacity PCB wastes, tpa
NA1	Mexico	S D Myers de Mexico S.A. de C.V. Benito Juarez No.102 Col. San Lucas Tepetlacalco, Naucalpan, Estado de Mexico Tel: 0052 5 398 5999 Fax: 0052 5 398 8150 Arturo Carrasco, President	Two chambers incinerator (1988)	9,000 (all wastes)
NA2	Canada	Bovar Waste Management, Swan Hills Treatment Centre Mail Bag 180 Swan Hills, Alberta T0G 2C0 Tel: 001 403 333-4197 Fax: 001 403 333-4196 Graham Latonas Vice President, Environmental Affairs	Rotary Kiln Incinerator (1994)	35,000
NA3	Canada	Bovar Waste Management, Swan Hills Treatment Centre (as NA2)	Rotary Kiln Incinerator (1990)	8,000
NA4	Canada	Cintec Environnement Inc. 2401 Lapierre Lasalle, Quebec H8N 17B Tel: 001 514 364-6860 Fax: 001 514 365-2964	Thermal Destruction System (mobile system)	
NA5	Canada	ELI Eco Logic International Ltd. 143 Dennis Street Rockwood, Ontario N0B 2K0 Tel: 001 519 856-9591 Fax: 001 519 856-9235	Thermal Destruction System (mobile system)	
NA6	Canada	Bennett Environmental Inc. Suite 200, 1130 West Pender Street Vancouver, B.C. V6E 4A4 Tel: 001 604 681-8828	Thermal Destruction System	

No	Country	Facility	Method	Capacity PCB wastes, tpa
		Fax: 001 604 681-6825		
NA7	Canada	PPM Canada Inc. 6 Chelsea Lane Brampton, Ontario L6T 3Y4 Tel: 001 905 790-7227 Fax: 001 905 790-7231	Dechlorination System - mobile and stationary facilities	
NA8	Canada	Sanexen Environmental Services Inc. 579 Le Breton Street Longueuil, Quebec J4G 1R9 Tel: 001 514 646-7878 Fax: 001 514 646-5127	Dechlorination System - mobile facility	
NA9	Canada	RONDAR Inc. 333 Centennial Parkway Hamilton, Ontario L8E 2X6 Tel: 001 905 561-2808 Fax: 001 905 573-8209	Dechlorination System - mobile facility	
NA10	Canada	Transformer and Switchgear Services Co. Limited 158 Wallace Street Woodbridge, Ontario L4L 2P4 Tel: 001 905 851-1803 Fax: 001 905 851-1803	Dechlorination System - mobile facility	
NA12	Canada	Ontario Hydro Technologies 800 Kipling Avenue Toronto, Ontario M8Z 5S4 Tel: 001 416 207-5876 Fax: 001 416 207-6094	Dechlorination System - mobile facility	
NA14	Canada	Manitoba Hydro 1840 Chevrier Blvd. Winnipeg, Manitoba R3T 1Y6 Tel: 001 204 474-4366 Fax: 001 204 474-4756	Dechlorination System - mobile facility	
NA16	Canada	B.C. Hydro 12388-88th Avenue	Dechlorination System - mobile facility	

No	Country	Facility	Method	Capacity PCB wastes, tpa
		Surrey, B.C. V3W 7R7 Tel: 001 604 590-7500 Fax: 001 604 590-5347		
NA17	USA	Safety-Kleen (Aragonite) Inc. Site: 11800 N. Aptus Road, Aragonite, UT 84029 Office: PO 22890, Salt Lake City, UT 84122-0890 Tel: 00 1 801 323 8100 Fax: 00 1 801 323 8884	Incinerator	
NA18	USA	Chemical Waste Management, PO Box 2563, Port Arthur, TX 77643 Tel: 00 1 409 736 2821	Incinerator	
NA19	USA	Laidlaw Environmental Services (Deer Park) Inc, PO Box 609, Deer Park, TX 77536 Tel: 00 1 713 930 2300	Incinerator	
NA20	USA	Weston One Weston Way, West Chester, PA 19380 Tel: 00 1 610 692 3030	Incinerator	
NA21	USA	Geosafe Corporation 2950 George Washington Way, Richland, WA 99352 Tel: 00 1 509 375 0710	Alternate Thermal Destruction	
NA22	USA	Commodore Remediation Technologies Inc, 1487 Delashmut Ave, Columbus, OH 43212 Tel: 00 1 614 297 0365	Chemical Dechlorination; Pipeline and Compressor Systems Decontamination	

No	Country	Facility	Method	Capacity PCB wastes, tpa
NA23	USA	ENSR Operations (formerly Sunohio) 1700 Gateway Blvd., S.E.Canton, OH 44707 Tel: 00 1 216 452 0837 www.ensr.com	Chemical Dechlorination; Physical Separation	
NA24	USA	Laidlaw Environmental Systems (PPM, Inc) 1875 Forge Street, Tucker, GA 30084 Tel: 00 1 770 934 0902	Chemical Dechlorination	
NA25	USA	Transformer Consultants (Div of S.D.Myers Inc). 180 South Avenue, Tallmadge, OH 44278 Tel: 00 1 800 444 9580	PCB Transformer Decommissioning (Disassembly/Smelting); Fluorescent Light Ballast Recycling	
NA26	USA	General Electric, One River Road, Schenectady, NY 12345 Tel: 00 1 518 385 0045	Physical Separation	
NA27	USA	Terra-Kleen Response Group, Inc. 3970-B Sorrento Valley Blvd., San Diego, CA 92130 Tel: 00 1 619 558 8762	Physical Separation	
NA28	USA	Environmental Technologies Unlimited Corp, 9220 Industrial Blvd., Leland, NC 28451 Tel: 00 1 910 371 2007	Pipeline and Compressor Systems Decontamination	
NA29	USA	Philip Environmental Services Corporation 3010 Greens Road, Houston, TX 77032 Tel: 00 1 713 442 1794	Pipeline and Compressor Systems Decontamination	
NA30	USA	Trans-Cycle Industries 101 Parkway East, Cogswell Industrial Park, Pell City,	PCB Transformer Decommissioning (Disassembly/Smelting);	

No	Country	Facility	Method	Capacity PCB wastes, tpa
		AL 35125 Tel: 00 1 205 338 9997	Fluorescent Light Ballast Recycling	
NA31	USA	Vector Group, Inc 1118 Ferris Road, Cincinnati, OH 45102 Tel: 00 1 513 752 8988	Pipeline and Compressor Systems Decontamination	
NA32	USA	Laidlaw Environmental Services (Tucker), Inc 1672 E. Highland Road, Twinsburg, OH 44087 Tel: 00 1 330 425 3825 Fax: 00 1 330 487 5784	PCB Transformer Decommissioning (Disassembly/Smelting)	
NA33	USA	FulCircle Ballast Recyclers 186 Brattle Street, Cambridge, MA 02138 Tel: 00 1 800 775 1516	Fluorescent Light Ballast Recycling	
NA34	USA	Salesco Systems USA. Inc.-AZ 5736 West Jefferson, Phoenix, AZ 85043 Tel: 00 1 800 368 9095	Fluorescent Light Ballast Recycling	
NA35	USA	H.E.L.P.E.R. 1606 NE 3rd St., Industrial Park, Madison, SD 57042 Tel: 00 1 605 256 6254	PCB Electrical Cable Processing for Metal Recovery	
NA36	USA	Chemical Waste Management Alabama Inc, Box 55, Emelle, AL 35459 Tel: 00 1 205 652 9721	Chemical Waste Landfill	
NA37	USA	Chemical Waste Management Box 471, Kettleman City, CA 93239 Tel: 00 1 209 386 9711	Chemical Waste Landfill	
NA38	USA	Chemical Waste Management of the Northwest, Star Route, Box	Chemical Waste Landfill	

No	Country	Facility	Method	Capacity PCB wastes, tpa
		9, Arlington, OR 98712 Tel: 00 1 503 454 2643		
NA39	USA	CWM Chemical Services Control, Inc. 1550 Balmer Road, Model City, NY 14107 Tel: 00 1 716 754 8231	Chemical Waste Landfill	
NA40	USA	Envirosafe Services Inc. of Idaho PO Box 16217, Boise, ID 83715-6217 Tel: 00 1 800 274 1516	Chemical Waste Landfill	
NA41	USA	Laidlaw Environmental Services (Lone & Grassy Mountain) Inc. (Grassy Mountain Facility) PO Box 22750, Salt Lake City, UT 84122 Tel: 00 1 801 323 8900 Fax: 00 1 801 323 8990	Chemical Waste Landfill	
NA42	USA	U.S. Ecology, Inc. Box 578, Beatty, NV 89003 Tel: 00 1 702 553 2203	Chemical Waste Landfill	
NA43	USA	Waste Control Specialists, LLC PO Box 1937, Pasadena, TX 77501 Tel: 00 1 713 944 5900 Fax: 00 1 713 944 5252	Chemical Waste Landfill	
NA44	USA	Wayne Disposal Inc. 1349 Huron Street South Belleville, Michigan 48197 Tel: 00 1 313 480 8085	Chemical Waste Landfill	

Table 15 Wastes Accepted and Services Provided at Facilities in North America

Facility	Wastes and equipment accepted												Services offered				
	pure PCBS	PCB-contaminated oils	PCB-containing items / materials	PCB-contaminated residues, sludge	PCB-contaminated soils	packaged / drummed waste		filled transformers	filled capacitors	emptied transformers	emptied capacitors		laboratory analysis / testing	PCB classification / labeling	PCB wastes transport	PCB waste packaging for shipment	clean-up of PCB contaminated sites
NA1	y	y	y	y				y		y							
NA2/3	y	y	y	y	y	y		y	y		y		y	y	y	y	y

8.8 RESPONDENT'S CONCERNS

A number of concerns expressed by questionnaire respondents are summarised below:

- large diameter cables holding PCB - Sweden
- large capacitors - Sweden
- implementation of treatment units in countries where there are substantial quantities of PCB waste, to avoid the risk of environmental pollution during storage - France
- transportation (sea and road) of PCB wastes and PCB waste equipment, including control and regulation to implement European legislation and the Basel Convention - France
- a sub-regional management plan based on developing national standards and management regulations, on a national inventory of PCB wastes, and on characterisation of waste streams before incineration - Cameroon
- dioxin emissions from heat treatment and incineration - The Netherlands
- mixing / diluting of PCB-waste with other waste streams and / or products - The Netherlands
- groundwater pollution, soil pollution and health problems for workers - Romania
- no real indication of world-wide quantities of PCBs, especially in the developing world - United Kingdom
- delays in receipt of imported wastes resulting from the differing requirements of regulators in the exporting and importing country - France
- opinion expressed that retrofilling with the transformer restored to service is preferable to destruction of transformers, particularly where this can be done without removing the transformer from its position - France.

Most of the above are of wider, though not universal, concern.

Management plans based on reliable waste inventories are an essential pre-requisite of an effective waste destruction programme. Segregation of waste streams greatly simplifies environmentally safe destruction of the most hazardous wastes. The management plans should also identify waste equipment of particular concern which may be difficult to treat because of its size or method of construction.

The management of combustion processes for waste streams to achieve dioxin concentrations in the gaseous emissions below limits set by the regulators, and to demonstrate to the public the effectiveness of the system in consistently achieving these levels, are essential features of good operational management of waste treatment facilities.

In Romania, and other countries where PCB wastes are stored but there are no available destruction facilities, possible pollution and health issues will be of concern until the wastes are destroyed, after either transport to a

described in Section 6 may be the most cost-effective method of waste destruction.

8.9 RESEARCH AND DEVELOPMENT NEEDS

Only four of the questionnaire respondents identified research and development needs, as summarised below:

- źero'emission process for conversion of PCBs into chlorine and other useful products - The Netherlands
- alternative solvent to tetrachloroethylene in solvent extraction processes - France
- allowing higher chlorine content of the cement kiln fuel without affecting the formation of dioxins and the quality of the cement - Indonesia
- a project on mutagenesis - Austria

Where cement kilns are available in countries lacking any other destruction facilities, they can represent an effective means of PCB destruction, but the effects on the combustion process both in terms of gaseous emissions and the quality of the product must be known and within acceptable limits.

The Austrian respondent provided no details of his suggested project.

8.10 SUMMARY

The questionnaire responses summarised above provide a useful body of information on the available facilities in Europe and Asia-Pacific. Few facilities were identified in Africa and Latin America, but a more complete response from these regions may not have identified many more facilities. The limited response to the questionnaire in North America, has been supplemented by lists of facilities provided by respondents and some information from the Secretariat of the Basel Convention.

Wastes and waste equipment accepted at identified facilities are indicated in Tables for the various regions. Incineration is the commonest method of waste destruction, in either purpose-built hazardous waste incinerators, and, in some countries, in cement kilns. Public acceptance of incineration is not universal and other methods of waste destruction are established commercially, especially in Australia and Canada.

On a global scale, the main problem in dealing with remaining waste PCBs and PCB-containing waste equipment is not the availability of technology, or of destruction facility capacity, but of identifying waste inventories (in some countries), and planning and financing their destruction. The best environmental option in some cases may involve cross-border transport of wastes.

Appendices

CONTENTS

Appendix 1

Copy of Questionnaire

PCB Destruction Capacity

POPs/PCB PROFILE INFORMATION REPORTING FORM - SECTION 12 SUP.

Section	Part 1 Survey of Global Destruction Capacity *(Please print or type)*
12.1	**Location of the PCB facility:** Name of Facility: ______ City / Country: ______ *(Provide address information in Part 2)*
12.2	**Type of facility:** ☐ Waste treatment/disposal ☐ Landfill ☐ Recycling Other:
12.3	**Licence / authorization:** Is this facility licensed or authorized to handle PCBs? ☐ Yes ☐ No Nature of licence / authorization if 'Yes': ______ Issuing authority *(name)*: ______ ☐ National *or* ☐ Regional / Local
12.4	**Disposal / treatment / recycling plant** (please identify)
	A) ☐ PCB disposal ☐ Rotary kiln incinerator ☐ Static kiln incinerator ☐ Liquid injection incinerator ☐ Fluidised bed incinerator ☐ Cement kiln ☐ Lime kiln ☐ Plasma arc process ☐ Landfill Other:______ _
	B) ☐ PCB treatment ☐ Chemical dechlorination ☐ Hydrodechlorination (hydrotreating) ☐ Infrared technology Other:______
	C) ☐ PCB-related recycling ☐ Retrofilling ☐ Solvent extraction ☐ Heat treatment Other:______
	D) New initiatives / technology *(please describe briefly):* ______
12.5	**Disposal / treatment performance:** *(Please fill in separately for each process by copying this section)* Name of method: ______ How classified in 12.4? *(e.g. rotary kiln incinerator)* ______ Year commissioned : ______ Efficiency : % HCl removal ______ % Destruction removal efficiencies (DREs) ______ Capacity estimates *(tonnes per year for main waste / equipment types)* : ______ Comments: ______ ______
	Name of method: ______ How classified in 12.4? *(e.g. rotary kiln incinerator)* ______ Year commissioned : ______ Efficiency : % HCl removal ______ % Destruction removal efficiencies (DREs) ______

	Capacity estimates *(tonnes per year for main waste / equipment types)* : __________ Comments: __________ __________

12.6	**Types of wastes accepted &** ☐ Pure PCB : ☐ PCB-contaminated oils : ☐ PCB-containing items / materials : ☐ PCB-contaminated residues, sludges: ☐ PCB-contaminated soils: ☐ Packaged / drummed waste Other :	**Limitation on waste accepted** *(please provide concentration ranges (max & min) and quantities for the waste types, and any other limitations)*
12.7	**Types of waste equipment accepted:** ☐ PCB-filled transformers ☐ Emptied transformers Others: ______ ☐ PCB-filled capacitors ☐ Emptied capacitors	
12.8	**For PCB-contaminated equipment only, give a brief description of the recycling process.** Identify the further processing of the product and waste streams produced *(i.e. whether component re-use, metal recycling, incineration, landfill disposal, other)* ; and process location:	
12.9	**Please provide information on storage at the facility including: capacity for the various PCB waste and equipment types, method, holding time.**	
12.10	**Emissions control** *(Please summarise for **air** and **water**)*	
12.11	**Worker protection** *(Please summarise **protective measures** applied during treatment of PCB wastes)*	
12.12	**Opinion box - PCB Management issues** *(Please describe briefly)* 1) What are your major concerns ? 2) Can you identify research and development needs in PCB management that would be beneficial for your region and waste managers world wide.	

PCB Destruction Capacity

POPs/PCB PROFILE INFORMATION REPORTING FORM - SECTION 12 SUP.

Part 2 Facility: Address and Service information

(Please print or type)

Facility Name: ____________________

Address: ____________________

____

City/Town: ____________________ **P.O. Box:** ____________________

District/State: ____________________ **Country:** ____________________

Telephone: ____________________ **Fax:** ____________________ **Email:** ____________________

Person completing form

Name: ____________________

Position: ____________________

Parent Company: *(if different)* ____________________

Address: ____________________

____

City/Town: ____________________ **P.O. Box:** ____________________

District/State: ____________________ **Country:** ____________________

Telephone: ____________________ **Fax:** ____________________ **Email:** ____________________

If more space is required for additional facilities please use a photocopy

Other Services offered

- ☐ laboratory analysis / testing
- ☐ PCB classification / labelling
- ☐ PCB wastes transport
- ☐ PCB waste packaging for shipment
- ☐ Clean-up of PCB contaminated sites
- Other PCB-related services *(please identify)******

* ____________________

____

Further information

Identify any company information (brochures, notes etc...) provided separately and if you wish provide additional comments on your services in **not** more than 50 words.

____

____

____

____

Appendix 2

Information Sources

Documents

Polychlorinated Biphenyls (Guidance on the drafting of Waste Management Licences), Department of Environment (UK), Waste Management Paper No 6, December 1994.

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Appendix 3

Technical Guidelines on Wastes Comprising or Containing PCBs, PCTs and PBBs

BASEL CONVENTION

ON THE CONTROL OF TRANSBOUNDARY MOVEMENTS
OF HAZARDOUS WASTES AND THEIR DISPOSAL

SECRETARIAT

TECHNICAL GUIDELINES ON WASTES COMPRISING OR CONTAINING PCBs, PCTs AND PBBs

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TECHNICAL GUIDELINES ON WASTES COMPRISING OR CONTAINING PCBs, PCTs AND PBBs

Production, use and waste arisings

1. This Guideline addresses the three classes of PCBs, PCTs and PBBs. PCBs represent by far the most significant group in terms of quantities originally produced, the volumes of waste requiring disposal, and the environmental significance of past, present and future waste disposal practices. PCBs have been studied much more than PCTs and PBBs, and hence the information available relates mainly to PCBs. In may respects, the three groups of substances display similar characteristics, and can cause similar problems if not handled properly.

2. PCBs, PCTs and PBBs are manufactured substances, which do not occur naturally. They all display excellent thermal stability and fire-resistance, and have thus found application in situations where fire-risk or thermal sensitivity might otherwise have been a problem. PCBs and PCTs also demonstrate good dielectric characteristics, rendering them particularly attractive for electrical equipment uses, such as transformers, capacitors and switchgear. Such uses are known as 'closed applications'. Other applications have included non-dispersive use as hydraulic and heat exchange fluids. Dispersing uses are being found in carbonless copying paper, adhesives, mixtures with pentachlorophenols for wood treatment, and in paints and varnishes. These uses are known as 'open-ended applications'.

3. PCBs were first commercially manufactured in around 1930, and production is believed to have finally ceased in the mid-1980s. At that time, well over one million tonnes were produced for all applications, worldwide, of which a significant portion is still in use. As awareness of the environmental problems associated with PCBs grew, its use was progressively restricted. 'Open-ended' applications, referred to in paragraph 2, were stopped in many countries during the early 1970s, and many electrical equipment manufacturers began to use other dielectric fluids where the requirements of the application permitted. Production of PCBs declined rapidly during the 1970s as uses became more and more restricted, and virtually ceased by the early 1980s.

4. PCBs have been supplied in commercial formulations under a variety of trade names. To assist in the recognition of PCBs containing products, a list of trade names is set out below.

Aceclor Phenoclor Pyralene	France
Santothern	France/UK
Therminol	France/USA

Clophen	Germany
Apirorlio	Italy
DK	
Fenchlor	
Kaneclor	Japan
Askarel	UK/USA
Aroclor	UK/USA
Ducanol	UK
Plastivar	
Pyroclor	
Asbestol	USA
Bakola 131	
Chlorextol	
Diaclor	
Dykanol	
Elemex	
Hydol	
Inerteen	
No Flamol	
Pydraul	
Pyranol	
Saft-Kuhl	
Solvol	USSR (now Russian Federation)

PCBs can be produced having different degrees of chlorine substitution, and hence different percentages of chlorine. Commercial formulations of PCBs fluids contained different degrees of chlorination depending on their intended application since the properties of the mixture, and hence its application varied with the degree of chlorination. For example, Aroclor 1242 containing 42% chlorine was used particularly as the dielectric in power supply control circuits, whereas Aroclor 1260 containing 60% chlorine and, because of its long term stability can be found in power transformers. Some formulations may contain solvents such as trichlorobenzene and tetrachlorobenzene, particularly in transformers, since their presence increase the fluidity of the coolant without detracting from its dielectric strength.

5. Polychlorinated terphenyls (PCTs) consist of three linked phenyl groups with varying levels of chlorine substitution. Properties of PCTs are very similar to those of PCBs, and hence the uses also show marked similarities. PCTs are generally solid at room temperature and may be encountered as resins, waxes or crystalline solids. Quantities used are very much lower than for PCBs, but include applications, the major ones being

investment (lost wax) casting, locating waxes employed in precision engineering and in sensitive pipe benching applications (nuclear pipework) as well as plasticizers, resins, adhesives, paper coatings, inks, waxes, fire-retardants, brake linings, abrasives and in electrical equipment as cable coatings, insulation and dielectrics and as a heat transfer medium.

Trade names for commercial formulations include:

Aroclor	USA
Leromoll	Germany
Clophen	Germany
Cloresil	Italy
Kanechlor	Japan
Phenoclor	France
Electrophenyl T-60	France

6. Polybrominated biphenyls (PBBs), have identical molecular structures to PCBs, but involve substitution of the molecule by bromine rather than chlorine. Technical and commercial formulations are typically white/grey/beige powders with high densities. Uses are largely related to the fire retardant properties provided to products into which they are incorporated and in particular plastics and mouldings, coatings and lacquers, and in polyurethane foams. Trade names for commercial formulations include:

Firemaster	USA
Bromkal	Germany
Adine	France
HFO 101	UK
Flammex	UK

7. The pattern and nature of PCBs waste arisings, and indeed ultimately the selection of a waste management option, requires special consideration which do not apply generally to other substances. First, since PCBs is no longer produced, and has not been for many years, the question of the adoption of clean technologies to avoid or minimize production wastes does not arise! Secondly, sales of PCBs into dispersive uses were successfully phased out from the middle 1970s, so the amounts still in circulation in such uses has been dramatically reduced. Traces can still however be found, in some products, such as waste paper, old in-service marine paints, etc. and in terms of environmental impact potential, these cannot be neglected. Thirdly, as a result of decisions and initiatives taken within bodies such as the North Sea Conference, and the European Community, there is a presumption against attempts to recycle or recover PCBs for reuse as such. This does not, however, preclude their use as a feedstock for the production of non-PCBs products.

In line with the declared intention of the above-referred bodies to remove PCBs and articles and products containing them from use within an accelerated timescale, it is considered that all products containing PCBs should not be allowed to be marketed or sold. Rather, they should be disposed of using approved destruction methods. However, taking into account the quantity of PCBs involved and the limited capacity available for its destruction worldwide, it may be appropriate that equipment containing PCBs, so long as it continues to function satisfactorily, is labelled and is subjected to regular inspections to confirm that it is in good condition and is not leaking, should be allowed to continue to be used until the end of its useful life. Then, at that time the equipment must be disposed of as a PCBs waste.

8. At the present time PCBs waste arisings fall into the main categories of:

- Capacitors, transformers or other items of electrical equipment containing commercial formulations consisting principally of PCB materials;

- Transformers which, originally having contained PCBs, but subsequently have been drained and refilled with a non-PCBs dielectric fluid which contains residual PCBs concentrations;

- Commercially formulated PCBs liquids drained from electrical equipment, or PCBs/solvent mixtures from the flushing and rinsing of such equipment;

- All other liquid wastes, including solvents and waste oils which may be described as secondary fuels;

- Any soil or other loose materials including absorbents.

9. In considering the question of PCBs wastes, particular note must be made of the problems of waste oil contaminated with PCBs. Concerns over the use of PCBs have caused some users of PCBs containing transformers to remove the PCBs liquid and replace it with another liquid. This practice, known as 'retrofilling' can itself result in problems, in that the internal design of the equipment can make it difficult to remove all the PCB, even when a flushing stage or stages using suitable solvent, is employed. Refilling the transformer with another fluid can result in that fluid becoming contaminated with PCBs to an extent that it would need to be regarded as a PCBs fluid for disposal purposes. Where the retrofilling fluid used was a mineral oil, it might be considered for use as a fuel. However, if used as such in a boiler furnace the presence of PCBs should be carefully evaluated to ensure that the combustion process does not produce dibenzodioxins and dibenzofurans which would be released to the environment in the combustion products. Also, where PCBs are being burned in high concentrations, the creation of HCl would create problems of acid corrosion for the materials of furnace construction.

Environmental and Health Effects

10. PCBs are lipophilic, so tend to accumulate in fatty tissues. They are thus found more frequently in animals than plants, and more in certain species of animal than others. PCBs accumulate in aqueous sediments, and may therefore be consumed in significant quantities by 'bottom feeding' marine species, and by insect larvae. Predatory birds such as ospreys and pelicans, which consume large quantities of potentially affected species may

themselves become significantly affected. PCBs display anti-oestrogen properties, and can thus inhibit calcium deposition during egg shell development, leading to insufficiently robust shells, and premature loss. PCBs may also display anti-androgen properties leading to adverse effects on male reproductive capabilities of bird and animal species.

11. In more specifically human terms, the toxic effects elicited by PCBs have included body weight loss, impaired immune function, teratogenicity and reproductive problems, dermal effects, a role in modulating carcinogensis and carcinogenicity, and effects on the liver. These responses are comparable to those of other halogenated aromatics such as the polychlorinated dibenzodioxins and dibenzofurans, and are believed to arise from a common ability - derived from molecular structural similarities - to act in a similar way within the body. Only a few of the PCB congenors exhibit the closest structural similarities, and these have been shown to be the most toxic.

12. Non-carcinogenic effects of PCBs include chloracne, a reversible dermatological problem, and effects on the central nervous system, causing headaches, dizziness, depression, nervousness and fatigue. Also included, and deriving from chronic exposure, are changes to the liver and related enzyme activities.

13. Carcinogenic effects represent the major toxicological effect of concern in human terms, although epidemiological studies have not been able to demonstrate any causal relationship between human PCBs exposures and increased risk of carcinogenesis. Studies on rats have been able to demonstrate a carcinogenic effect, and have led to all commercial PCBs formulations being denoted as 'probable human carcinogens'. More detailed analysis of the studies has concluded that in causing rodent liver tumours, PCBs are promoters rather than initiators of carcinogenesis, and furthermore, that only a very few of the PCB congeners are responsible for carcinogenic activity.

14. It must be noted that considerable scientific work on the environmental and health effects of PCBs is in progress worldwide.

Measures for Waste Avoidance and Minimization

15. As already explained, PCBs are no longer manufactured, and many of the commodities which contained them have long since passed through the waste management cycle. Waste avoidance and minimization are therefore somewhat different considerations with PCBs, and are largely confined to the careful control of electrical equipment still in use, and containing in total substantial tonnages of PCBs products. These are, principally electrical transformers and power factor correction capacitors - little else will qualify, and certainly nothing else on a substantial or significant scale.

16. Waste avoidance and minimization therefore, must focus on the avoidance of leakages and spillages from such equipment. The effective containment, collection and storage of any minor leakages and spillages which might occur is essential. Extreme care at the time of servicing the equipment is important. Those engaged in servicing equipment should be specially trained in clean-up procedures. When the equipment is finally taken

out of service measures must be taken to handle the equipment in a safe manner and place it in secure storage prior to disposal. Care must be taken to avoid losses and especially to avoid contamination of the storage building and other materials stored there, including wastes, to avoid increasing the quantity of materials needing to be classified as PCBs and thus requiring special disposal. Any pre-treatment or storage activity related to transportation or final disposal must similarly reflect the requirement to avoid leakages and spillages and to ensure containment of all the waste up to its moment of disposal.

When PCBs, PCBs-contaminated materials, and PCBs-contaminated mineral oils cannot be treated or disposed of upon their decommissioning, they must be stored in a manner which:

a. Minimizes risks to the environment through transportation;

b. Avoids leakages and spillages;

c. Ensures containment of all wastes up to its moment of treatment and disposal.

PCBs waste in storage must be clearly labelled as such and registered with their country's competent authorities. Long term storage of PCBs wastes could be practised provided that measures are taken for their proper treatment and disposal.

Recovery Technologies

17. It is no longer considered environmentally sound practice to seek to recover PCBs although this has been done in the past by the use of vacuum distillation techniques.

18. Previous paragraphs have explained how PCBs may be present in waste oils and solvents, and it is certainly possible that recovery of oil or solvent may be desirable for commercial reasons. However, in such cases, special care must be taken in the disposal of the residues from the recovery operations since these will contain PCBs at a much higher concentration than in the original, larger volume of waste.

19. Use of waste oils and solvents as a fuel can be regarded as recovery, insofar as beneficial use is made of the energy content of a waste. However, uncontrolled use as a fuel should not be interpreted as being regarded as a preferred or environmentally sound management practice. Waste oils and solvents containing significant concentrations of PCBs should *not* be used as fuels unless burned in facilities which are designed, operated and regulated to ensure adequate and safe destruction. They should be considered as PCBs waste, and subjected to approved, appropriate disposal methods under domestic legislation.

20. The only recovery operation for which PCBs wastes have been used is when the waste provided a chlorine rich feed material in the production of hydrochloric acid. Combustion of PCBs in air enriched with oxygen will produce hydrochloric acid gas which

can be scrubbed out of the process gas stream, subjected to concentration and clean-up stages and provide a commercial grade acid. Normally, the economics of the process are considered not to be attractive, particularly as there is scant demand for hydrochloric acid in many countries. Usually, other manufacturing activities already produce a surplus of the acid. However, the process has been used on a limited scale in cases where special conditions prevail.

Treatment and Disposal Technologies

21. Treatment and disposal methods and practices divide into those which seek to destroy the PCBs, and those which place it in a depository for long term storage in which it is hoped that it will remain contained. Disposal technologies must be capable of breaking up PCBs molecules into products exhibiting less harmful properties. Disposal of PCBs requires a significant amount of energy which usually involve the use of supplementary fuel. Landfilling should be regarded as a method for disposing of PCBs contaminated wastes, only in exceptional and limited cases where very dilute or slightly contaminated material is involved, or very small dispersed sources of PCBs are involved. So-called long-term storage of equipment and articles containing PCBs, possibly after removal of any free liquid, is practised using special stores, underground vaults or old mine workings. The intention in these cases is that the wastes should be accessible for treatment and/or disposal in the future. Incorporation of PCBs waste in waste solidification processes or encapsulation of articles in, for example, concrete - both with a view to landfilling of the product - would not normally be considered appropriate as it would be regarded as storage in a situation which was not controlled or controllable.

22. Several technologies have been demonstrated as being capable of destroying PCBs efficiently. Many other technologies can destroy PCBs, but have yet to be developed to the point where an acceptable efficiency of destruction can be demonstrated and commercial value assessed. Still more technologies exist which might well be capable of PCBs destruction, but which have not yet been tested.

23. High temperature incineration is a well-established and proven technology for the disposal of PCBs and PCBs containing wastes. Incineration involves the degradation of waste by thermal energy in the presence of oxygen. The judicious selection of combustion chamber design, and the type of gas cleaning and arrestment equipment needed, can provide designs to handle most organically based waste in almost any physical form. Appropriate designs of incineration plant is capable of dealing with concentrated PCBs liquids, solid PCBs contaminated items and articles such as capacitors, pieces of transformers, and drums, and low contamination wastes such as packaging and soil contaminated with traces of PCBs. Incinerators for disposing of liquids and pumpable sludges only, can be of a more straightforward design than those intended for solid wastes. In all cases incinerators intended to handle PCBs must be capable of high destruction efficiency such as 99.9999%. Such destruction efficiency could be obtained through a sustained operation at temperatures of around 1200°C which include an independently temperature controlled post-combustion chamber, provide a gas-phase residence time of at least two seconds, efficient acid gas-scrubbing plant, and sophisticated control equipment.

24. Cement kilns provide temperature profiles and gas residence times which equate to if not exceed those of specialized waste incinerators. Both test and commercial burns have demonstrated destruction efficiencies of 99.9999%. Cement kilns are not necessarily fitted with the sophisticated broad spectrum capability gas cleaning systems necessary to meet the standards required of state-of-the-art integrated incinerators dealing with a wide range of wastes. Facilities without such control systems should not be used for waste disposal. The limitations on the capacity of suitably equipped processors and the need to ensure that there are no adverse effects on product quality, impose restrictions on input. PCBs in high concentrations alone or in capacitors, which will normally require shredding, will need to be blend in at a low rate, though the high through-put in cement kilns will still equate to significant quantities. The greater opportunity for cement kilns is in the burning of oils contaminated with low levels of PCBs which represent a valuable form of low-cost energy to what is an energy-intensive process (energy can equate up to 1/3 of process costs), whilst also offering a potential source of chlorine required when using certain raw materials to meet product quality requirements. Some Governments may however prohibit such practices.

25. Chemical dechlorination methods are used in some specialist applications of PCBs treatment and destruction. They involve the use of powerful and reactive reducing agents such as metallic sodium, which can chemically strip the chlorine atoms from the PCB molecule, and in some instances at least, partially break down the remaining molecule. While this technology can, in principle, be applied to concentrated PCBs liquid waste streams, generally it is considered not to be an attractive economic option. The process is particularly useful for treatment of mineral based transformer oils which have become contaminated with PCBs - typically to a concentration of a few hundred to several thousand ppm. The reagent does not affect the base oil itself but breaks down the PCBs to form a residue which may be removed by physical separation. In the hands of skilled and expert operators, such processes could be carried out even whilst a transformer is in use, and operating. Other closed loop disposal technologies potentially appropriate for the destruction of PCBs are becoming available. These include catalytic, physiochemical, electrochemical and chemical treatment methods.

26. Specialist supporting equipment may be necessary for the pre-processing and handling of PCBs wastes. This may include equipment for the controlled shredding of articles such as capacitors, and for the careful emptying, flushing, dismantling, dismemberment and decontamination of larger items of equipment such as transformers. Decontamination can take place by "roasting" pieces of equipment in an incinerator, by use of a solvent washing vacuum autoclave, or by other mechanical means.

27. All plant and equipment used for the processing, treatment and disposal of hazardous wastes, including PCBs wastes, must be designed according to sound engineering practice, and fabricated and installed in conformity with recognised standards. Relevant engineering drawings should be readily available, and should relate to all parts of the equipment, and cover all necessary features of its operation. Drawings should be kept up to date in line with any alterations and modifications made to the equipment.

28. Disposal costs for PCBs wastes are high, and reflect the capital intensive equipment needed, the sophisticated operational and control regime required, and the extensive infrastructure which must be provided. Disposal charges for incineration of PCBs wastes vary significantly with the physical form of the waste, and the PCBs or chlorine concentration. For example, in Europe concentrated PCBs liquids may fall typically into the range of $US 1000-2000 per tonne, and solids such as capacitors and transformers some 50% higher at $US 2000 - 3000 per tonne. High calorific value solvents and oils with very low PCBs contents may, in exceptional circumstances, attract an income but will more usually be accepted for disposal at charges of up to $US 200 per tonne. These charges do not include transportation to the disposal site!