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Matters related to the implementation of the Convention: measures to reduce or eliminate releases from intentional production and use: polychlorinated biphenyls

Draft guidance for development of PCB inventories and analysis of PCB

Note by the Secretariat

As is mentioned in the note by the Secretariat on polychlorinated biphenyls (UNEP/POPS/COP.10/6), the annex to the present note sets out a draft guidance on a standardized approach to developing Inventories of PCB, entitled "Draft Guidance for Development of PCB Inventories and Analysis of PCB" prepared by the small intersessional working group on PCB. The present note, including its annex, has not been formally edited.

* In accordance with decisions BC-15/1, RC-10/2 and SC-10/2 of the conferences of the Parties to the Basel, Rotterdam and Stockholm conventions, the 2021/2022 meetings of the conferences of the Parties are being held in two segments: an online segment held from 26 to 30 July 2021 and a face-to-face segment to be held from 6 to 17 June 2022 in Geneva.

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Annex

Draft Guidance for Development of PCB Inventories and Analysis of PCB

February 2022

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Disclaimer:

This report was prepared by the small intersessional working group on polychlorinated biphenyls (PCB SIWG). The PCB SIWG was established through decision SC-9/3 and tasked, among others, prepare guidance on a standardized approach to developing inventories of polychlorinated biphenyls and to analysis for the identification and quantification of PCB.

In the event of any inconsistency or conflict between the information contained in the present non-binding guidance document and the Stockholm Convention on Persistent Organic Pollutants, the text of the Convention takes precedence, taking into account that the interpretation of the Stockholm Convention remains the prerogative of the Parties.

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List of Abbreviations

Askarel	most common (trade) name to refer to any combination of PCB and chlorinated benzenes
ASTM	American Society for Testing and Materials, West Conshohocken, PA, USA
CEN	Comité Européen de Normalisation, European Committee for Standardization (en), Brussels, Belgium
CHF	Swiss franc (currency code)
ECD	electron capture detector
EN	European norm
EPRI	Electric Power Research Institute, Palo Alto, CA, USA
IARC	International Agency for Research on Cancer
IEC	International Electrotechnical Commission, Geneva, Switzerland
ISO	International Organization for Standardization, Geneva, Switzerland
NOAA	National Oceanic and Atmospheric Administration (United States of America)
PCB	polychlorinated biphenyls
SC	refers to decisions from the Conference of the Parties to the Stockholm Convention
SI	Système international d'unités, International System of Units (en)
USEPA	United States Environmental Protection Agency

1 Introduction

1.1 Background

The small intersessional working group on polychlorinated biphenyls (PCB) established through decision SC-8/3, in its report and the recommendations submitted to the Conference of the Parties at its ninth meeting, identified the need for guidance on a standardized approach to developing inventories of PCB and to analysis for the identification and quantification of PCB.

It should be noted that according to the provisions of the Stockholm Convention on Persistent Organic Pollutants (POPs) and Article 6, the guidance should provide clear and ready-to-implement advice on its development and application. The two time-limited goals in the Convention are set for 2025 and 2028; thus, there would be only two inventories needed.

The objectives of the guidelines are to respond to decision SC-9/3, assist Parties in the development of a common approach to generate comparable information towards elimination of use of PCB.

It should be noted that time is the main constraint in the development and implementation of the guidance, including the evaluation of the inventory information. Only a short period remains to fully achieve the objectives.

Subsequently, the guidance should be realistic and achievable according to the reporting obligations and the regulatory objectives of the Convention.

The guidance is aimed to be used by Parties during a four-year period to accumulate national information and submit it through the electronic reporting format to the Secretariat. Parties that have already developed their PCB inventory are encouraged to fill in the relevant sections in the summary and periodical tables with their previous inventory/inventories to complete the information and cover the whole period starting with the date of entry into force of the Stockholm Convention; i.e., year 2004.

This report was prepared by the small intersessional working group on polychlorinated biphenyls (SIWG PCB) as a response to decision SC-9/3 to prepare guidance on a standardized approach to developing inventories of PCB and to analysis for the identification and quantification of PCB.

PCB are a class of aromatic compounds comprising 209 congeners, each containing one to ten chlorine atoms attached to a biphenyl nucleus. Technical PCB products, which were manufactured to obtain a specific level of chlorination, are mixtures of many PCB congeners obtained through the production process, i.e., chlorination in the presence of a catalyst. These products were produced in large amounts by a limited number of companies but widely used geographically (*i.e.*, worldwide) and in many applications as dielectric fluid in capacitors and transformers, and to a lesser extent in building materials (*e.g.,* caulking, paints, and lighting ballasts). A working group convened by the International Agency for Research on Cancer (IARC) found sufficient evidence of carcinogenicity in humans and experimental animals to classify all PCB (of whatever definition) as carcinogenic to humans (Group 1) (IARC, 2016; Lauby-Secretan et al., 2013).

As this guidance was prepared in 2021, Parties are approaching the end of the “action period” for PCB management bearing in mind that adoption of the text of the Stockholm Convention already occurred in 2001 and there are only four years remaining to meet the 2025 goals. It is assumed that all Parties have taken the necessary steps, institutional and legally, to fulfil the requirements on PCB under the Convention. Therefore, when institutions, entities, etc. are mentioned below, no advice is given as to the justification of such entities rather the assignment of specific tasks and outputs. In addition, financial aspects are not addressed.

1.2 Objectives of these guidelines

To achieve the goals of the Stockholm Convention for PCB, “homework” has to be completed first, starting with a reliable PCB assessment, followed by choice of an appropriate technology for destruction of PCB. Throughout the process, priority setting has to be applied.

In order to do so, complete inventories have to be prepared using clear definitions and goals since errors or gaps in the estimation of the PCB amount will result in insufficient characterization of the problem and not achieve the goals of elimination.

The objectives of the guidance are as follows:

- Support implementation of Article 6 of the Stockholm Convention;

- Allow assessment of progress towards elimination of PCB (2025 and 2028 goals of the Stockholm Convention);
- Parties to demonstrate the elimination of PCB in all equipment by 2025 and the environmentally sound management of PCB until 2028 or report progress towards elimination of PCB.

1.3 Legal reference

1.3.1 Stockholm Convention

Polychlorinated biphenyls (PCB) are listed in Annex A to the Stockholm Convention on Persistent Organic Pollutants with a specific exemption for the continued use of PCB in articles in accordance with the provisions of Part II of Annex A, to be exercised by all Parties to the Convention. The production of PCB and new uses are prohibited, and equipment containing PCB shall not be exported or imported except for the purpose of environmentally sound waste management.

According to Part II of Annex A, each Party shall take action towards the elimination of the use of PCB in equipment (e.g., transformers, capacitors or other receptacles containing liquid stocks) by 2025, subject to review by the Conference of the Parties. Equipment containing PCB greater than 0.005% (50 mg/kg) and volumes greater than 0.05 L should be identified and removed from use.

Part II of Annex A also provides that each Party shall make determined efforts designed to lead to environmentally sound waste management of liquids containing PCB and equipment contaminated with PCB having a PCB content above 0.005% (50 mg/kg), in accordance with paragraph 1 of Article 6, as soon as possible but no later than 2028, subject to review by the Conference of the Parties.

In accordance with Article 15 of the Convention, each Party shall report to the Conference of the Parties on the measures it has taken to implement the provisions of the Convention and on the effectiveness of such measures. Information on progress in eliminating PCB is reported in part C of national reports pursuant to Article 15. The national reports can be viewed at the Convention's webpage http://www.pops.int/Countries/Reporting/NationalReports/tabid/3668/Default.aspx.

1.3.2 Basel Convention

Since all PCB become waste, Parties to the Basel Convention have to take into account the obligations under the Basel Convention as refers to reporting on export (Table 4) and import (Table 5) of hazardous waste. PCB-relevant waste streams according to Annex I 'Categories of wastes to be controlled' are designated as 'Y10' (UNEP, 1992). The national reports can be viewed at the Basel Convention's webpage http://www.basel.int/Countries/NationalReporting/NationalReports/BC2019Reports/tabid/8645/Default.aspx.

Waste types that may contain PCB can be found in Annex VIII of the Basel Convention in List A (*i.e.,* metal and metal-bearing wastes in A1180 and A1190 that may be hazardous due to the presence of PCB).

For PCB waste, the Basel POPs waste general technical guidelines (UNEP, 2021) and the specific PCB technical guideline (UNEP, 2017) should be consulted.

1.4 Definitions

The chemical structure of PCB is shown in **Error! Reference source not found.**. The possible positions of chlorine atoms on the benzene rings are denoted by numbers assigned to the carbon atoms.

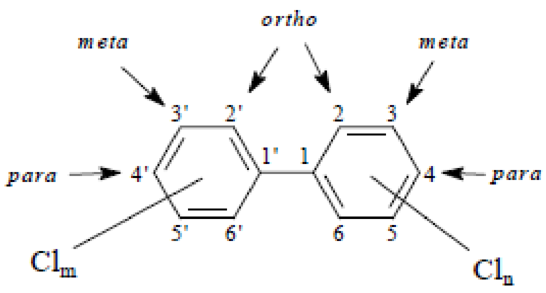


Figure 1: Chemical structure of PCB (m and n are the number of chlorines in each ring)

PCB, as listed in Annex A of the Stockholm Convention, are commercial products that have been produced industrially for a number of uses. In the Stockholm Convention and according to Article 3, Article 6 and Annex A Part I, PCB are from intentional production. Unintentionally produced PCB as defined in Article 5 and Annex C, are not included in this guidance.

Also not specifically addressed for this guidance are the 12 dioxin-like PCB (dl-PCB) that have been assigned a toxic equivalency factor (TEF) by an expert group of the World Health Organization (WHO) (van den Berg et al., 2006) as they are not specified by the listing under Annex A of the Convention.

Commercial PCB mixtures were manufactured by flowing chlorine gas through biphenyl until the desired weight percent of chlorine was achieved. This process allowed for the production of PCB with different levels of chlorination. To our knowledge, all producers of commercial PCB used such process; therefore, the various commercial products should be similar. The chemical composition is quite well defined for the commercial products produced in the United States of America, Japan and Germany; less is known about those manufactured in other countries (Table 1).

Table 2 provides a list of producers and trade names. Compositions of commercial products can be found in the IARC volume of PCB (IARC, 2016).

Analytically, PCB are not easy to separate into the 209 congeners (for methods, see section 7 - Determination of PCB), but typically they have a chlorine content between 20% and 60%. Information regarding the type of PCB can be derived from the commercial names; however, it shall be noted that the numbers in the trade names for Aroclors and Clophens have different meanings:

- In Aroclors (Monsanto production), the first two digits refer to either the 1100 (crude product) or the 1200 (distilled product from the 1100 series) series. The 3rd and 4th digits give the chlorine content in percent. Thus, Aroclor 1254 contains 54% of bound chlorine in the molecule. The average number of chlorine atoms in the molecule is 4.9. All commercial products are from the 1200 series with the exception of Aroclor 1016, which is a more biodegradable product and obtained through distillation from Aroclor 1242 with the highly chlorinated congeners removed;
- In Clophens (Bayer production), the second last digit gives the average number of chlorines in the molecule. Thus, Clophen A30 contains three chlorines per molecule corresponding to 41.3% bound chlorine;
- Based on the above, Aroclor 1260 roughly corresponds to Clophen A60.

The definition of 'PCB' in the inventory (and the national reporting) should be clearly defined as either

- Only the liquids contained in the equipment (in a strict sense from Annex A, Part II); or
- Including the contaminated (parts of the) equipment having been in contact with the PCB liquid, which would constitute the total amount – as mass in tonne (t) or volume in litre (L) - to be managed.

In order to make inventories and progress reporting comparable and consistent, the reports should maintain the same structure and approach.

1.4.1 Practical implications

1.4.1.1 Article 6

Article 6 of the Stockholm Convention requires Parties to prepare a dynamic inventory of PCB. Specifications in Annex A, Part II define volumes/mass and concentrations for cut-off (UNEP, 2001). The smallest volume is 0.05 litre (L), corresponding to 50 millilitre (mL), and the lowest concentration is 0.0005 percent, corresponding to 50 milligram (mg) per litre (mg/L). The text of Annex A, Part II is reproduced in Appendix section 8.1).

The actions on PCB imply a dynamic inventory and documentation of all of the actions as shown below:

- Identify;
- Label; and
- Remove from use.

1.4.1.2 Article 15

Further legal reference is given by Article 15 National reporting. Accordingly, each Party is required to report on:

- Total quantities of its production, import and export of PCB or a reasonable estimate of such data;

- Countries/Parties from which a Party has imported PCB and countries/Parties to which a Party has exported PCB;
- The measures the Party has taken to implement the provisions of PCB elimination and on the effectiveness of such measures in meeting the objectives of the Convention.

1.4.2 Quantitative approach using this guidance

The Stockholm Convention refers to amounts of PCB in 'percent' and in 'litre'. Part II of Annex A, does not specify percent as weight per cent (as is done in Annex A for decabromodiphenyl ether or short-chain chlorinated paraffins and in Notes below the table in Annex A in sub-paragraph (vii) Note (i). It shall be noted that 'litre' refers to a volume and not to a mass.

It is a general recommendation and common practice or requirement to report the presence of chemicals, including PCB and other POPs, according to the seven base units of the International System of Units (SI). The base unit for 'mass' (dimension symbol 'M') is kilogram (kg). Additionally, the low POP content, developed by the Basel Convention bodies, analytical determinations, and many (if not all) regulations refer to PCB as mass concentration and report amounts in mg/kg on a mass basis.

For simplification and international practice, and despite PCB typically have higher density than 1 (e.g., 1.54), a conversion of 1/1 for volume/mass is being applied. Thus, an amount of 0.005% per litre is referred to as 50 mg/kg. Reporting measured amounts from a laboratory is referred to in sections 4.4 or 7.5 or 0.

It is important that the reporting Party maintains the same quantification unit throughout the reporting in each reporting cycle (national reports, NIPs).

2 Outline of the Guidance

This guidance document contains the following:

Chapter 1 - Introduction provides background and legal reference to the Stockholm and Basel conventions, followed by the definition and requirements for PCB in equipment and in open applications;

Chapter 2 - Outline of the Guidance;

Chapter 4 - Inventory for PCB in Equipment and Applications provides the basis for the development of the mandatory reporting for PCB in equipment;

Chapter 5 - Inventory for PCB in open applications;

Chapter 6 - Preparation of Summary Inventory addresses the summation of the activities in the reporting format;

Chapter 7 - Determination of PCB contains the analytical guidance;

Chapter 8 - Appendix 1 includes additional information;

Chapter **Error! Reference source not found.** contains the bibliographic references.

3 Organization of the PCB inventory development

3.1 General

The following key elements should be considered in the preparation of the guidance and are applicable for both parts (i) inventory guidance and (ii) analytical determination of PCB:

- Scope, timelines, accountability (responsible actors, recipient of information, user of information, etc.);
- Unified nomenclature and definitions (include equipment, material and amounts or values);
- Harmonized approaches, robust but flexible, concise;
- Output compatibility with the format for national reporting under the Stockholm Convention;
- Harmonization with and allowing input from the national reporting under the Basel Convention;
- Ease of replication and updating;

- Documentation on the methods used for quantification/inventory would be helpful. At present not requested in the national reporting form but may be helpful to demonstrate comparability between different periods within a country.

The flowchart in Figure 2 below depicts the steps for decision making as to inclusion of information in the quantitative inventory (adapted from (UNEP, 2010)). It can be seen that at three steps, a decision can be made to assign any equipment as 'PCB-containing' or as 'PCB-free'. The decision as to which step such identification is sufficient is done according to national regulation or definition. The various steps and implications are detailed in chapter 4 and especially in sections 4.3 and 4.4. The analytical steps are detailed in sections 7.2, 7.4 and 7.5.

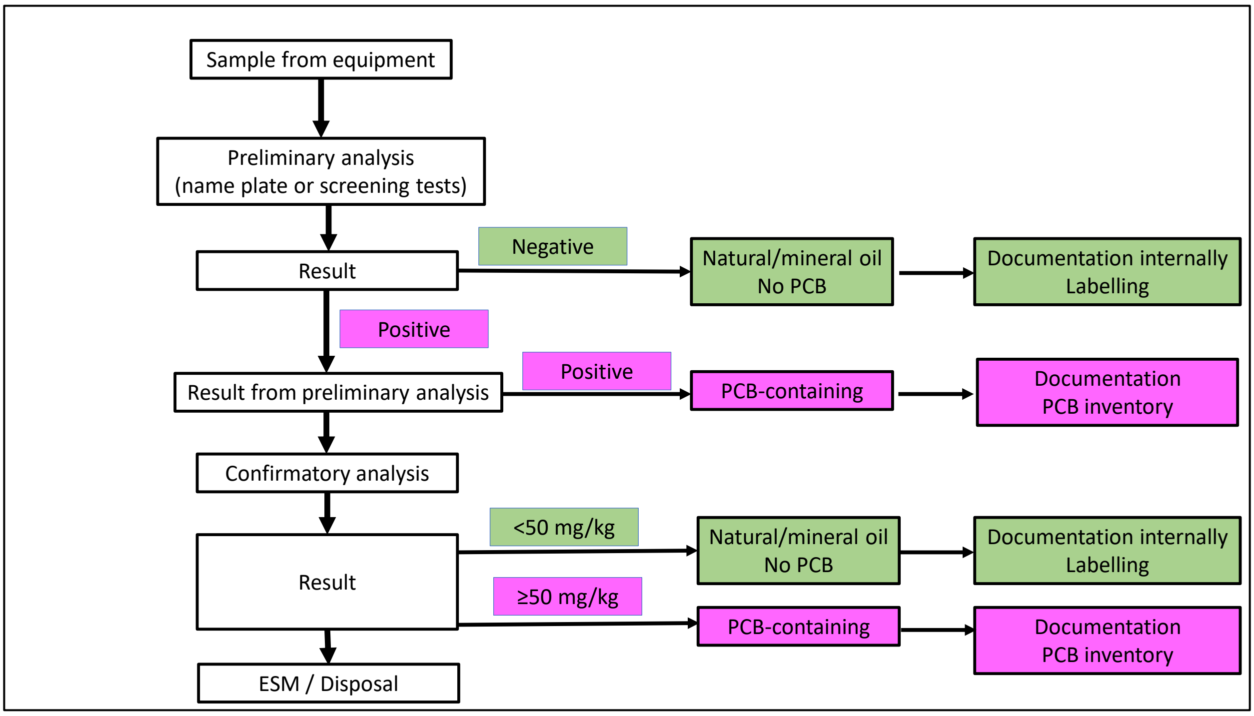


Figure 2: Flow chart for determining and reporting progress in elimination of PCB

3.2 Definition or classification for (types of) PCB under this guidance

PCB have not been produced or used as a single compound but rather as complex mixtures. The most well-known PCB products are Aroclor, Clophen, Phenochlor, Kanechlor, Pyralene, Fenclor, and Delor (for countries of origin, see Table 1). Trade names of commercial mixtures are given in

Table 2 together with their main uses in either transformers (trans) or capacitors (cap). The commercial products were manufactured towards meeting a defined degree of chlorination to fulfil technical requirements.

Table 1: Names of commercial PCB and country of origin

Country	Commercial product	Country	Commercial product
China	PCB	Czechoslovakia (former)	Delor
France	Phenoclor, Pyralene	Japan	Kanechlor
Germany	Clophen	Soviet Union (former)	Sovol, Sovtol, trichlorodiphenyl
Italy	Fenoclor	United States of America	Aroclor

Table 2: Trade names from producers of PCB

Asbestol (trans, cap)	Hydol (trans, cap)
Askarel	Kanechlor (trans, cap)
Bakola 131 (trans, cap)	Montar
Biclor (cap)	Nepolin

Asbestol (trans, cap)	Hydol (trans, cap)
Chlorextol (trans)	No-Flamol (trans, cap)
Chlorinol	Phenoclor (trans, cap)
Clophen (trans, cap)	Pydraul
Clorphen (trans)	Pyralene (trans, cap)
Delor	Pyranol (trans, cap)
Duconol (cap)	Pyroclor (trans)
Dykanol (trans, cap)	Saf-T-Kuhl (trans, cap)
EEC-18	Santotherm FR
Elemex (trans, cap)	Santovac 1, Santovac 2
Eucarel	Siclonyl (cap)
Fenchlor (trans, cap)	Solvol (trans, cap)
Elemex (trans, cap)	Sovol
Hivar (cap)	Therminol FR

Each trade name may correspond to one or several products with varying chlorine content. Denominations in parenthesis denote use in transformers (trans) or capacitors (cap)

3.3 Inventory for PCB in equipment

The Stockholm Convention requires Parties to make determined efforts to identify, label and remove from use equipment containing PCB at specified amounts (UNEP, 2001). Therefore, the inventory for PCB in equipment or PCB liquids in receptacles (often referred to as “closed applications”) is mandatory and is contained in the summary inventory table (to be detailed in chapter 6).

Since less than five years are left to achieve the 2025 goal, it does not seem reasonable to maintain the tiered approach as referred to in Annex A, Part II of the Convention (as reproduced in Appendix section 8.1). Rather all PCB from the smallest volumes (=0.05 L, corresponding to 50 mL) and the lowest concentration (0.005 %, corresponding to 50 mg/L) should be merged into one final number according to the classifications proposed in this guidance document. Equipment containing less than 0.005% is considered ‘No PCB’ and not included in the quantitative PCB inventory.

For the purpose of this guidance and reporting progress in elimination of PCB for Article 15 of the Stockholm Convention, equipment containing PCB equal or greater than 0.005% should be classified as ‘PCB-containing’ and equipment containing less than 0.005% PCB as ‘No PCB’. Equipment classified as PCB-containing must be reported in the national inventory and the format according to Article 15; equipment classified as No PCB are not reported in the national reporting but can – on a voluntary basis – be documented in the national inventory (and the NIP); however, not merged with amounts of PCB at or above 0.05%.

No alternative differentiation as to high- and low-density PCB will be made. Although some countries refer to equipment with a PCB content between 0.0002% and 0.005% as equipment with ‘residual PCB’, such differentiation will not be made in this guidance and for the national reporting. For analytical implications using lower levels, see section 0.

For the purpose of measuring PCB in different parts of the equipment or waste, two cases should be considered; the result of the analysis for metal non-porous surfaces (e.g. ferrous metal of the casing, copper, aluminium) should be reported in terms of µg/100 cm². Other materials or waste such as paper, wood, contaminated soils, among others, should be reported in mg/kg.

In summary:

Definition	Description	Concentration and Unit
‘No PCB’	PCB content in liquids is less than 0.005%	<50 mg/kg
‘PCB-containing’	PCB content is equal or greater than 0.05%	≥50 mg/kg

3.4 Inventory for open applications

The inventory for open application is voluntary according to decision SC-9/3 and is contained in the summary inventory table (Chapter 6). The cut-off concentration is the same as for PCB in equipment, i.e., at or greater than 0.005% or 50 mg/kg.

4 Inventory for PCB in Equipment and Applications

4.1 Objective and structure

All activities should be targeted to meet the summary format for inventory reporting, which is shown in Table 5.

In a preparatory step, the format from Table 5 is expanded to allow stepwise compilation from individual surveys for testing and to differentiate between equipment type – transformer, capacitor, receptacle – and where possible between casings and liquids.

4.2 Types and owners of PCB-containing equipment

4.2.1 Relevant sectors having PCB in use or storage

All entities having PCB-containing or PCB-contaminated equipment in use or just out of use (short-term temporary storage) awaiting first step in disposal should be identified. In this context, Annex VIII of the Basel Convention should be consulted; List A with codes A1180 and A1190 specifies metal and metal-bearing wastes that may be hazardous due to the presence of PCB.

Transformer: is a device that allows raising or lowering the voltage in a circuit by means of a magnetic field, maintaining the same power. Its operation is based on the principle of electromagnetic induction.

Transformer oil or insulating oil: primary function of the transformer oil is to insulate and cool a transformer. In order to fulfill this function, the oil must have high dielectric strength, thermal conductivity, and chemical stability.

Capacitors: exist in many forms, styles, lengths, girths, and from many materials. They all contain at least two electrical conductors (called "plates") separated by an insulating layer (called the dielectric). Capacitors are widely used as parts of electrical circuits in many common electrical devices. Capacitors, together with resistors and inductors, belong to the group of "passive components" used in electronic equipment.

Designations such as ceramic or paper capacitors refer to the material of the dielectric; i.e., ceramic or paper.

The list of equipment containing PCB is shown below in Table 3. The equipment is divided into the three groups as listed in Annex A (left column). The functionality describes the PCB use and the right column provides indicative examples, whereby most of them were taken from the UNEP/PEN report (UNEP, 2016b) Table 2-3)).

Table 3: Equipment containing PCB according to application and location

Equipment	PCB functionality	Examples
Transformers	Dielectric fluid	Large: industrial facilities, public buildings, hospitals, hotels
		Small: railroad vehicles, vessels; dental offices
Capacitors	Dielectric fluid	Large: Power factor correction capacitors; Fixed paper capacitors for motors, capacitors for direct currents, for accumulation of electricity
		Small: Motor start capacitors, light ballasts and capacitor for fluorescent lights and mercury lamps; Household electrical appliances, such as air-conditioners, washing machines, monochrome television sets, and microwave ovens
Other receptacles	Dielectric fluid	High voltage switches, circuit breakers, voltage regulators, liquid filled electrical cables

Equipment	PCB functionality	Examples
	Hydraulic fluids	Hydraulic fluids as heat medium (heating and cooling in mining equipment; aluminum, copper, steel, and iron industries
	Heat transfer fluids	As heating and cooling agent in various chemical, food and synthetic resin industry. Preheating agent of the fuel oil of vessels, central heating systems, and panel heaters
	Lubricating oil	In vacuum pumps, electronic components manufacture; laboratory, instrument and research applications; and waste water discharge sites

4.2.2 Relevant institutions having PCB in storage or for disposal

It is recommended that the national PCB coordinator maintains a list with:

- Entities that have PCB received from third party (former) owners, handle PCB for the next disposal step (disaggregation? Dismantling? Recovery? Destruction?). This includes importers for PCB from abroad. These entities should be consulted and report a quantitative inventory;
- Entities that are undertaking the final step in PCB elimination within the country for either destruction or export.

4.2.3 Entities for disposal

Includes entities that dispose of nationally and export or import PCB for the purpose of environmentally sound disposal (they are expected to match the quantitative inventory). Both are to be included and quantified in the inventory form (see Table 4).

4.3 Screening, semi-quantitative inventory

The term 'PCB-assumed' is mostly used to refer to classify liquids and equipment that have not been tested for PCB content. This approach for inventory purposes, used in some countries, considers the equipment, liquid or waste as containing greater than 0.005% PCB until further laboratory analysis can specify the PCB content (UNEP, 2019).

In a first step, the country may survey only the number of equipment suspect to contain PCB and initially only count or estimate the number of pieces and separate the equipment into the three large groups transformers, capacitors and receptacles.

If a country decides that information obtained from optical inspection such as indicators from nameplates, density tests or semiquantitative determination is sufficient, the country should convert the number of pieces into (estimated) weights in kg and enter the amounts into the inventory form (Table 4).

4.4 Quantitative Inventory

The quantitative inventory contains the information on the presence or suspected presence of PCB as PCB at or above the limit are confirmed. Once becoming waste, a decision as to whether the equipment has ⩾50 mg/kg or <50 mg/kg or another national limit value (in mg/kg) has to be taken by the government. These initially suspected amounts of PCB from the inventory will result in the equipment being declared either 'No PCB', which does not need special controls under the Stockholm or Basel convention provisions or 'PCB-containing', which needs to be managed according to the provisions of the Basel Convention.

The model is shown in Table 4 and provided as a separate Microsoft Excel file on the Stockholm Convention website (http://chm.pops.int/Implementation/IndustrialPOPs/PCB/Evaluation(review)/tabid/8304/Default.aspx). Note: only cells with no coloured background should be filled in; all coloured cells have formula and will be calculated.

If no differentiation between casing (here: contains also other solid materials such as copper cables, paper, etc.) and liquid can be made, the total weight can be entered as a hard number into the 'subtotal' column for either transformer, capacitor or other receptacle.

If countries have identified and classified PCB-containing materials as either liquids, utensils, casings, construction materials, or contaminated soil, and have them stored in barrels (for transport to destruction facility), these amounts should be entered as ‘Other Receptacles’ in the form, Table 4 (either as a total with a hard number or separately). These numbers are subsequently aggregated in the same columns in Table 5 for the summary inventory and national reporting forms.

In order to facilitate the data management, it is recommended to maintain the 4-year period inventory development in kilogramme (kg) and not in tonne (t). Although the numbers may become quite large, individual transformers, capacitors or other equipment most likely will have the information on name plates provided in kg (and not in t).

It is recommended that the approach used for the determination of PCB is added; e.g., based on:

- Optical inspection;
- Test kits or chloride-specific electrode analyzer;
- Targeted analysis with GC/ECD or GC/MS, including method of calculation (Aroclor pattern, total PCB determination or sum of 6 indicator PCB multiplied by factor of 5) should be added.

A simple coding system is proposed to indicate the PCB determination approach and is to be inserted into the inventory format (Table 4). For transformers, capacitors and receptacles the column ‘method” is added to include the designations as shown in Table 10.

Table 4: Expanded inventory form to prepare for the national reporting form (or summary inventory); here: during the reporting period 2018-2021

Period		Period 2018-2021														
Application	PCB definition	Total			Transformers				Capacitors				Receptacles			
Amounts (kg)	(mg/kg)	Subtotal (kg)	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid/Semi-liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)
PCB in use (kg)		**56,600**	**37,600**	**19,000**	**42,500**		**35,000**	**7,500**	**11,100**		**600**	**10,500**	**3,000**		**2,000**	**1,000**
Survey 1		13,000	10,500	2,500	12,000	S1	10,000	2,000	1,000	R or R1	500	500	-			
Survey 2		15,600	5,100	10,500	5,500	D	5,000	500	10,100	R or R3	100	10,000	-			
Survey 3		28,000	22,000	6,000	25,000		20,000	5,000	-				3,000		2,000	1,000
PCB in storage/out of use (kg)		**51,400**	**35,000**	**16,400**	**36,400**		**35,000**	**1,400**	**10,000**		**-**	**10,000**	**5,000**		**-**	**5,000**
Survey 1		21,000	20,000	1,000	21,000		20,000	1,000	-				-			
Survey 2		10,400	10,000	400	10,400		10,000	400	-				-			
Survey 3		20,000	5,000	15,000	5,000		5,000		10,000			10,000	5,000			5,000
Subtotal (active) inventory (kg)		**108,000**	**72,600**	**35,400**	**78,900**		**70,000**	**8,900**	**21,100**		**600**	**20,500**	**8,000**		**2,000**	**6,000**
PCB disposed of/treated/destroyed (kg)	**PCB definition (mg/kg)**	**69,650**	**63,100**	**6,550**	**48,700**		**47,000**	**1,700**	**15,950**		**12,100**	**3,850**	**5,000**		**4,000**	**1,000**
at national level		**5,200**	**4,000**	**1,200**	**2,700**		**2,000**	**700**	**2,500**		**2,000**	**500**	**-**		**-**	**-**
Survey 1		2,700	2,000	700	2,700		2,000	700	-		-	-	-		-	-
Survey 2		2,500	2,000	500	-		-	-	2,500		2,000	500	-		-	-
Survey 3		-	-	-	-		-	-	-		-	-	-		-	-
exported for destruction (kg)		**59,800**	**56,000**	**3,800**	**45,000**		**45,000**	**-**	**13,300**		**10,000**	**3,300**	**1,500**		**1,000**	**500**
Survey 1		38,500	36,000	2,500	30,000		30,000		7,000		5,000	2,000	1,500		1,000	500
Survey 2		15,000	14,000	1,000	10,000		10,000		5,000		4,000	1,000	-			
Survey 3		6,300	6,000	300	5,000		5,000		1,300		1,000	300	-			
imported for destruction (kg)		**4,650**	**3,100**	**1,550**	**1,000**		**-**	**1,000**	**150**		**100**	**50**	**3,500**		**3,000**	**500**
Survey 1		1,000	-	1,000	1,000			1,000	-				-			
Survey 2		150	100	50	-				150		100	50	-			
Survey 3		3,500	3,000	500	-				-				3,500		3,000	500
Application		Total			Transformers				Capacitors				Receptacles			
Amounts (kg)		Subtotal (kg)	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid/Semi-liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)
Material recovered from inventory (kg)		**3,000**	3,000	-	**2,000**		**2,000**	-	-		-	-	**1,000**		**1,000**	-
Survey 1		2,000	2,000	-	2,000		2,000		-				-			
Survey 2		-	-	-	-				-				-			
Survey 3		1,000	1,000	-	-				-				1,000		1,000	
Balance in reporting period (kg)		**66,650**	**60,100**	**6,550**	**46,700**		**45,000**	**1,700**	**15,950**		**12,100**	**3,850**	**4,000**		**3,000**	**1,000**
Application		Total			Transformers				Capacitors				Receptacles			
		Subtotal (kg)	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid/Semi-liquid (kg)	Subtotal (kg)	Method	Casing (kg)	Liquid (kg)
Actual Inventory - Amounts (kg)		**174,650**	**132,700**	**41,950**	**125,600**		**115,000**	**10,600**	**37,050**		**12,700**	**24,350**	**12,000**		**5,000**	**7,000**
Control				174,650				125,600				37,050				12,000

5 Inventory for PCB in open applications

Due to their chemical characteristics and physical stability, PCB products were widely used in open and partially open applications. It is generally believed that PCB were used in open applications between the 1950s and the early 1980s. However, the time of usage of PCB in the different applications can vary from country to country.

The percentage of PCB in the materials highly depends on the type of application, the product itself, and the manufacturer. Concentrations can vary considerably and may reach up to 80% PCB. Open applications are not usually defined as hazardous waste at the time of disposal, so PCB often find their way into the environment, e.g., as construction debris. PCB from open applications can also be released into the environment by weathering and inappropriate removal of PCB containing materials.

Examples of relevant open applications in which PCB can be found include the following:

- Caulks/sealants;
- Paints/plaster;
- Anti-corrosion coatings;
- Cable sheaths;
- Flame retardants;
- Adhesives;
- Impregnating agents;
- Carbonless paper.

Indicative classification may wish to differentiate between cable sheaths, cured caulk and painted objects (to replace TBD in the draft summary table Table 5).

Some examples for open applications are shown in Appendix 2 by providing some pictures to facilitate identification upon first inspections (see photographic impressions on PCB in open applications in section 8.2 with details in sections 8.3.1 for PCB in public and residential building and section 8.3.2 for PCB in machinery and installations).

From (UNEP, 2016b) Table 2-3)) the following applications are extracted:

Paints and inks	Carbonless papers (solvents), electronic type copying papers, paints for fire-resistance, corrosion-resistance, chemical-resistance, and waterproof printing inks
Plasticizer	Caulking/sealants for insulation, mixed to adhesives, varnish, wax, and asphalt as flame retardant
Other dissipative usage	Coating of papers, sealants of cars, colouring of China glassware, color television parts, the effect extension agents of agricultural chemicals, oil additive agent

Masonry buildings constructed or renovated between about 1950 and the late 1970s may contain PCB in materials such as caulking and paint, sometimes in very high concentrations (Herrick, 2010; Herrick et al., 2016).

According to Herrick (Herrick et al., 2016), caulking materials (in US schools) contained Aroclor 1254 and mixtures close to Aroclor 1242. PCB sealants appear to contain more volatile PCB with a dominance of PCB 28 and PCB 52.

6 Preparation of Summary Inventory

Compiling and aggregating sectoral information into the agreed summary inventory table (for reporting to the BRS Secretariat) is the final step in the inventory development.

Note: Annex A, Part II refers to PCB either without specification, ‘receptacles containing liquid stocks’ or ‘equipment containing polychlorinated biphenyls’. The inventory form should – at least in an initial step - allow to differentiate between ‘liquid PCB’ and “materials suspect of containing or contaminated with PCB”, to be added or subtracted from the ‘subtotal PCB’.

The Table 5 below is compiled automatically from the entries in Table 4.

Additional information as to the determination of PCB can be added if feasible by including information using Table 10.

Table 5: Final inventory format to report PCB management during the reporting period 2018-2021

PCB inventory summay (4-year period)					TBS: to be specified		
Period	Period 2018-2021						
Application	PCB in Equipment (mandatory)				Open Application (voluntary)		
Amounts (kg)	Subtotal (kg)	Transformers (kg)	Capacitors (kg)	Other Receptacles (kg)	Subtotal (kg)	TBS (kg)	TBS (kg)
PCB in use	56,600	42,500	11,100	3,000	0		
PCB in storage/out of use	51,400	36,400	10,000	5,000	0		
Subtotal (active) inventory (kg)	**108,000**	**78,900**	**21,100**	**8,000**	**0**	**0**	**0**
PCB disposed of/treated/destroyed (kg)	**69,650**	**48,700**	**15,950**	**5,000**	**0**	**0**	**0**
at national level	5,200	2,700	2,500	-	0		
exported for destruction	59,800	45,000	13,300	1,500	0		
imported for destruction	4,650	1,000	150	3,500	0		
Material recovered from inventory (kg)	3,000	2,000	-	1,000	0	0	0
Balance in reporting period (kg)	**66,650**	**46,700**	**15,950**	**4,000**			
Actual Inventory (kg)	**174,650**	**125,600**	**37,050**	**12,000**	**0**	**0**	**0**

7 Determination of PCB

In a first step, the whole PCB determination approach including sampling and chemical analytical procedures, should be agreed upon and documented.

Laboratory analyses of PCB are undertaken to determine compliance with Annex A part II and subpoints contained therein (cf Annex A, Part II a i)-iii) and f) in particular). Chemical analyses in the laboratory are not necessary in all cases to identify PCB. In some cases, a descriptive label may be sufficient for trained and experienced personnel for correct interpretation of the observation (UNEP, 2019).

7.1 Sampling

The sampling approach should be documented at all times whether chemical analysis is undertaken or not. Also, in cases where only optical inspection is undertaken to characterize the equipment that have been surveyed; this should be documented. In the expanded inventory format, Table 4, it is recommended to group the activities for the inventory updating into separate ‘surveys’, which refers to distinct activities. A ‘survey’ may consist of a regional/local inventory, a time-limited project, or even an outcome that has not yet generated final quantification/results. The latter ones may be referred to as ‘suspect’ and would remain in the inventory until final determination and classification.

7.1.1 Source (UNEP, 2016b)

Although the lack of sampling and analysis is a common shortcoming for many PCB inventories in developing countries, it is recommended that the sampling is undertaken only by professional staff or fully trained operators equipped with adequate personal protection equipment. A strict quality assurance (QA)/quality control (QC) procedure should be followed to get representative and non-contaminated samples.

7.1.1.1 Sampling transformer oils

Oil samples can be taken using the drain tap which is usually located at the bottom of the transformer. The standard operation procedure (ASTM D 3613 92) of syringe sampling and metal cylinder sampling could be followed for the sampling of transformer oil. Transformers can be sampled using a hand pump via the oil filling cap. However, the oil taken from the expansion receptacle is not representative and cannot be used as a sample for PCB analysis, because it does not circulate and thus it is not sufficiently mixed. Normally, 0.2 mL oil is enough for quantitative analysis of PCB.

7.1.1.2 Sampling capacitor oils

It is advisable only to sample capacitors that are already out of service. Capacitors still in service and manufactured before 1993 with missing information about the dielectric liquid have to be labeled as PCB suspect equipment. In the event that no data is available, it is best to label these with a yellow ‘suspect’ label and take a sample at the end of their service life before 2025.

If there is a series of the same capacitors, it is usually sufficient to sample only two devices out of the series. If a designation is missing and relevant information from the manufacturer is not available, the only way to test the dielectric liquid is to drill a hole in the casing at the top or cut the isolator and retrieve an oil sample. This can be done by using a pipette (use only once). After this exercise, the capacitor is unusable and, as it is now damaged, it must be stored in appropriate manner.

7.1.2 PEN magazine (UNEP, 2010)

It is recommended to sample and analyze for PCB; therefore, all electrical devices not hermetically sealed should be sampled even if they were recently manufactured, because unintentional contamination could have occurred.

Oil samples can be taken by using the drain tap which usually is at the bottom of the transformer.

If a transformer has been disconnected from power for over 72 hours, the sample should be taken from the bottom as PCB sink due to their higher density. Sometimes the gasket gets damaged when the drain tap is opened. It is therefore advisable to always have a spare gasket ready.

Alternatively, transformers can be sampled via the oil filling cap by using a hand pump (note: a new hand pump must be used for each transformer). Oil samples from the expansion receptacle cannot always be regarded as representative, because the oil does not circulate and thus it is not really mixed.

Usually, transformers are sampled when they are in use and thus when they are electrically alive. Relevant protective measures and safety regulations must be known and introduced at all times!

If the oil quality is to be tested, the following steps have to be considered:

- Sampling via drain tap: Drain off about 1 L of oil first in order to clean the drain from particles which might have accumulated in that area;
- Amount of oil required: 0.2 L to 1 L (in case of oil quality analysis);
- Leave the oil for 24 hours, in order to allow particles and water to settle;
- Take sample from the upper third of the oil for the analysis using a pipette;
- Return the drained oil back into the transformer (only if the oil filling cap is out of reach of the high voltage and oil is without heavy impurities, otherwise shut off the transformer before refilling oil).

7.2 Desktop approach

7.2.1 Qualitative inventory

The qualitative inventory consists of a listing of items or issues to be considered, including type of equipment surveyed, methods of documentation, and identification of needs for follow up. The qualitative inventory can already include counts of equipment or locations for further investigation. The preliminary inventory is used for scoping, and orientation and has to be completed by a quantification step, which at least would consist of optical inspection (see section 7.2.2) but preferentially by more elaborated steps (sections 7.4 or 7.5).

7.2.2 Optical inspection according to certain parameters

Name plates have been attached (fixed) to transformers and capacitors at the time of manufacture or start of application/operation. They give reliable information concerning the dielectric fluid, cooling system and weight/mass. Typically, a name plate fixed on a transformer or capacitor provides the following:

- Name of manufacturer;
- Date of production;
- Power (kVA);
- Serial number;
- Trade name of the dielectric fluid;
- Total mass, mass of dielectric fluid;
- Cooling system(s) in case of transformers.

Since not all combinations are possible, missing information can be concluded by referring to information from Table 1,

Table 2, Table 6, and Table 7.

Usually, a transformer has more than one cooling system to allow flexibility and supplemental cooling equipment can be set to run only at increased loads. Methods of cooling for liquid-immersed transformers[1] have been arranged into cooling classes identified by a four-letter designation as shown in Table 6. The 4-letter cooling classes have been developed through standardization between different international standards organizations and replace earlier classifications (mainly used in the U.S.). The 4-letter code refers to internal and external parameters and classifies the medium and the mechanism. As an example, the former OA classified a liquid-immersed self-cooled transformer in the U.S. in the past; in the new system, the designation would be ONAN. Similarly, the previous FA classification is now identified as ONAF.

Transformers containing PCB would have a designation starting with 'L' for 'liquid with no measurable flash point'. Thus, LNAN on the name plate indicates that transformer contained PCB at the time of the manufacture.

If the plate name shows ON or ONAN, the type of the cooling fluid implies to be PCB-free (caution: cross contamination might have occurred during maintenance).

Table 6: Cooling class letter description (https://electrical-engineering-portal.com/transformer-cooling-classes)

		Letter		Description
Internal	First letter (Cooling medium)	O		Liquid with flash point less than or equal to 300 °C
		K		Liquid with flash point greater than 300 °C
		L		Liquid with no measurable flash point
	Second letter (Cooling mechanism)	N		Natural convection through cooling equipment and windings
		F		Forced circulation through cooling equipment, natural convection in windings
		D		Forced circulation through cooling equipment, directed flow in man windings
External	Third letter (Cooling medium)	A		Air
		W		Water
	Fourth letter (Cooling mechanism)	N		Natural convection
		F		Forced circulation

[1] The second types are dry-type transformers.

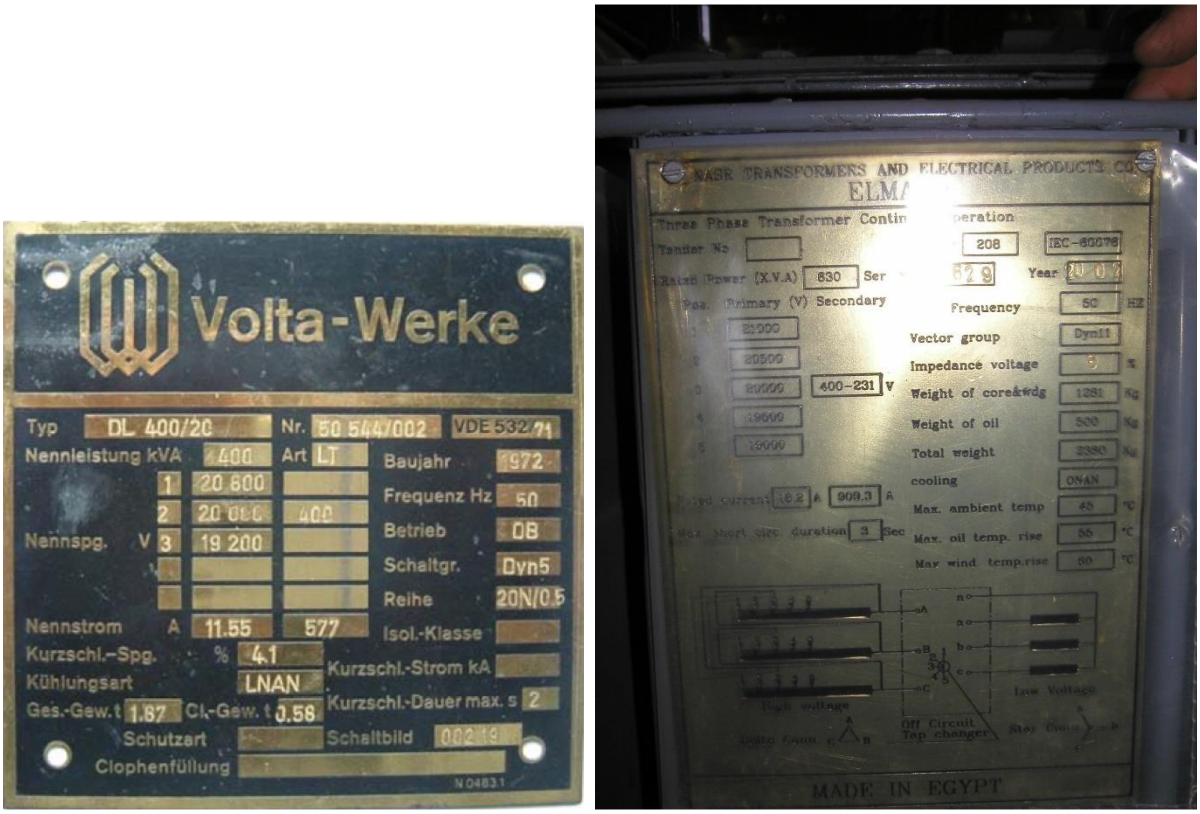


Figure 3: Name plates from transformers: left = containing PCB (Kühlungsart LNAN) and right – not containing PCB (cooling = ONAN)

Photos; courtesy Michael Mueller (left), Heidelore Fiedler (right))

It shall be noted that PCB in capacitors can be labelled differently (see Figure 4).

Figure 4: Example for name plates from capacitors. Left: Tränkmittel (= liquid) CpA 30 refers to Clophen A30 (source (Müller, 2011); right: 'Pyranol' refers to commercial PCB product (source (UNEP, 2010)

Nameplates of transformers manufactured under the IEC 60076 standard after 1976 have the codes as shown in Table 7. The codes indicating PCB containing liquids (filled at the time of manufacture) are highlighted in grey and include combinations **CNAN** or **LNAN**. In combination with forced air at either inner or outer cooling or both, the codes would be CNAF, CFAF for Clophens or LNAF, LFAF for Askarels.

It shall be noted that 'Clophen' and 'Askarel' are only two trade names for PCB-containing products. Using these codes, 'Clophen' has to be extended to include all known PCB trade names (for reference see

Table 2).

ONAN implies that mineral oil was used and the transformer does not contain PCB from the manufacturer. However, it should be checked that no cross-contamination occurred during maintenance upon exchange of oil.

Table 7: Symbols used on nameplates of transformers manufactured after 1976 and using the IEC 60076 cooling codes (reproduced from https://issuu.com/pcbsmed/docs/short_guide_to_identify_pcb_s_febru)

1^{st} letter		2^{nd} letter	3^{rd} letter	4^{th} letter
C or L or O		N or F	A	N or F
Type of inner coolant		Mode of circulation of inner coolant	Type of outer coolant	Mode of circulation of the outer coolant
PCB	Mineral oil	N = Natural F = Forced	A = Air	N = Natural F = Forced
C = Clophen L = Askarel	O = Mineral oil			

These 4-letter codes for the cooling system refer to:

- 'Natural' mode of circulation of the inner coolant (2^{nd} letter) means that the transformer is cooled by the natural flow of the dielectric fluid, without use of pumps;
- 'Natural' mode of circulation of the outer coolant (4^{th} letter) means that the transformer is cooled only by ambient air without the use of fans;
- 'Forced' mode of circulation of the inner and out coolants (2^{nd} and 4^{th} letters): the cooling of the transformer is supported by pumps (inner coolant) and/or by fans (outer coolant = air).

Japan had produced and used PCB mainly in the domestic market; examples of nameplates are shown in Figure 6.

7.2.2.1 Producer or trade name

The names of commercial products include Aroclor, Clophen, Phenochlor, Kanechlor, Pyralene, Fenclor, and Delor (IARC, 2016). For details, see section 3.2.

7.2.2.2 Year of installation of original equipment

The year of installation or refilling, as well as maintenance records, can provide important information as to the probability of presence or absence of PCB. Since most PCB have been produced between 1950 and 1980, plaques and labels referring to this period would serve as an indication that the dielectric fluid may consist of or contain PCB (UNEP, 2019).

7.2.2.3 Cross-contamination

Due to accidental contamination during electrical maintenance work, we can find transformers with dielectric mineral oil or silicon contaminated with PCB. This process is called "cross-contamination". Cross-contamination is produced either by direct contact or by the use of accessories and elements of equipment with PCB, thus transferring the contaminant to the dielectric oil.

7.2.3 Reporting aspects if Party decides to accept these results as the final inventory

Amounts of PCB estimated by using the density test, shall be reported in the inventory format (Table 4) with the method from Table 10 indicated.

7.3 Screening by applying density test

In the case that transformers are present and their liquids need testing, the density test can be used as an initial orientation. It is recommended that such tests are done only in cases where transformers have been topped up with PCB dielectrics and maintenance records are available and not full exchange of liquids have occurred.

The density test is done by filling a glass vial with about 5 mL of water and adding 5 mL of the transformer oil. Since PCB liquids have higher density than water (1.3 and above; most likely around 1.5), the oily PCB phase will sink to the bottom of the vial (as will do polychlorinated naphthalenes (PCN) if these have been used as PCB replacements). In case that the transformer contained mineral or natural oil, these oils will float on top of water since both liquids are lighter than water (because they are not halogenated). It shall be noted that the lighter oily phase can contain amounts of PCB above the limit of 50 mg/kg but is dissolved in the mineral oil phase with a total density slightly below 1 (density of water).

In case of silicone oils, they have a density similar to water (0.96 kg/L) and a water content of 30%, such tests may lead to erroneous conclusions.

In the Figure 5 below, transformer oils were sampled in Erlenmeyer flasks (left); the colour of the oil is not an indicator for chemical identity of the liquid. At the right side of Figure 5, it can be seen that the coloured oil phase is always above the clear water phase except for the 4th vial from left, where there is an oily phase above and a small phase below the water. The lower phase is suspect to contain PCB (at relevant amounts).

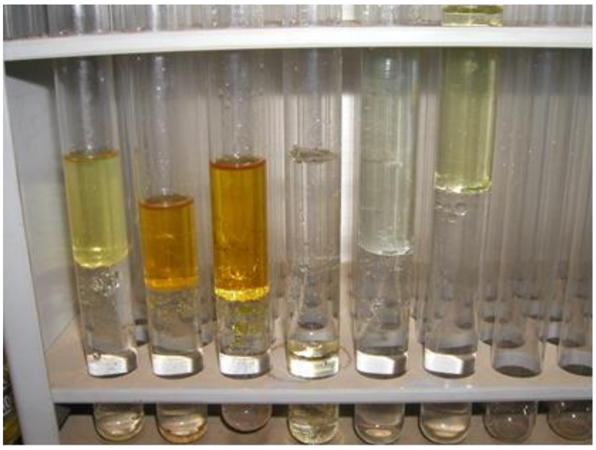


Figure 5: Density test: transformer oils sampled (left); transformer oils with water in test tubes (right)

Table 8: Density relation (UNEP, 2016a)

	Askarel	Natural/mineral oil
Empty weight of transformer	3000 kg	3000 kg
Volume	1000 L	1000 L
Density	1.6 kg/L	0.87 kg/L
Mass of coolant	1600 kg	870 kg
Total mass of transformer	4600 kg	3870 kg
Ratio total mass/mass of liquid	2.9	4.5

7.4 Test kits or sum parameters

This section provides an overview on approaches to determine the content of PCB in liquids contained in equipment. The PCB content of the casings (equipment) or articles containing or contaminated with PCB is not addressed in this section; although the gas-chromatographic methods can be applied to other matrices and if steps in the laboratory concerning sample preparation, extraction and clean-up are adapted accordingly. The test kit described in section is applicable to transformer oils of petroleum oil origin only.

In this section, care has to be taken as to the definition of the analyte since some approaches determine PCB as a whole and are calibrated to Aroclor 1242 (with an average of 5 chlorines per molecule).

7.4.1 Test kits for fixed endpoint colorimetric test

Method 9079 is a method to screen hydrocarbon based electrical insulating fluids for polychlorinated biphenyls (PCB) at concentrations of 20 mg/kg, 50 mg/kg, 100 mg/kg, or 500 mg/kg (method 9079 states units in µg/g) (USEPA, 1996). The method is designed to provide screening data outside of a laboratory environment in less than 10 minutes. The PCB concentration above or below the fixed end-point is provided by a colorimetric indication. The result is either positive or negative towards the action level; here 50 mg/kg. The method will reveal whether a sample is above or below 50 mg/kg but will not tell whether a sample contains 70 mg/kg or 80 mg/kg. When the kit registers below 50 mg/kg (purple colour), however, the darker the colour, the closer the amount of PCB in the sample is to zero.

The method is based on the basic principle to measure the total chlorine content in a hydrocarbon and convert the result to an equivalent concentration of the target analyte (here: PCB). In order to do so, all organic chlorine (chlorine covalently bound to carbon atoms) must be converted to chloride (= inorganic chlorine anion) and the number of chlorine ions calibrated to a PCB source (here Aroclor). In the commercial test kit - Clor-N-Oil test kits by

Dexsil – are calibrated on Aroclor 1242, commonly found in electrical insulating fluids. Aroclor 1242 contains 42% of chlorine by weight; thus, less than Aroclor 1254 or Aroclor 1260 (60% of chlorine by weight). By calibrating the test kits using Aroclor 1242, the most conservative result is obtained.

For reaction, the hydraulic fluid sample – containing the organic chlorine - is reacted with metallic sodium in the presence of a catalyst and the resulting (free) chloride is extracted into an aqueous buffer solution and reacted with dissolved mercuric nitrate. A colour indicator, sensitive to mercuric ions, is then added. If there are more mercuric ions than chloride ions, the free mercuric ions react with the indicator resulting in a purple colour, indicating less than 50 mg/kg PCB. If the number of chloride ions is equal to or greater than the number of mercuric ions, then all the mercuric ions are associated with the chloride ions and no mercuric ions are fee to react with the indicator; thus, no purple colour can develop. The result is a pale yellow or colourless solution revealing the presence of greater than 50 mg/kg PCB (ETI, 2021 (accessed)-a).

The Clor-N-Oil PCB screening was developed by the Electric Power Research Institute (EPRI) in response to the U.S. EPA's decision to restrict the use of, and eventually remove from service, all electrical equipment containing PCB contaminated insulating fluid. Dexsil Corporation (Hamden, CT, USA) manufactures and markets the Clor-N-Oil kit. The test is designed to test only transformer oil of petroleum oil origin. The test is not applicable to other types of oil, e.g., used motor oil or other types of lubricants or industrial oils (Dexsil, No year; ETI, 2021 (accessed)-a; USEPA, 1996).

To perform the test, one test kit is needed, and 5 mL of transformer oil is added. Since the test works on chloride detection, any external source of chloride, such as salt or sea water, must be avoided since will result in false positives. The test should be performed in a warm, dry area and with adequate light. The test kit will not work on samples that contain water. Since no instruments are required, tests can be performed on-site. The analysis time is less than five minutes.

Used Clor-N-Oil kits should be disposed of as PCB waste (ETI, 2021 (accessed)-a).

Because the Clor-N-Oil test is based on total chlorine analysis, it is recommended to undertake subsequent GC/ECD or GC/MS analysis since a positive result may occur when the sample is contaminated by an organochlorine source other than PCB.

7.4.2 PCB analyzer

The L2000DX analyzer relies on the same basic chemistry as the Clor-N-Oil test kits, however instead of a colorimetric reaction, the L2000DX uses an ion-specific (chloride) electrode to quantify the contamination in the sample (ETI, 2021 (accessed)-b). The instrument can be applied for the determination of all types of chlorinated hydrocarbons including PCB in soil, water, transformer oil or surface wipe samples. The test uses a metallic sodium reagent to strip the covalently bonded chlorine off the organic molecule. The resultant chloride is transferred in an aqueous buffered solution for analysis either in the field or the laboratory. The instrument uses a chloride-specific electrode to quantify the extracted chloride. The associated programme converts the chloride into 28 chlorinated compounds and converts the chloride concentration to mass concentrations (ppb, ppm or µg/100 cm^2 of the target analyte. The L2000DX analyzer is pre-programmed with conversion factors for major Aroclors such as Aroclor 1242, Aroclor 1254, and Aroclor 1260; in addition, results for Askarel A can be read. Less common Aroclors, such as Aroclor 1221, can be programmed. The built-in methods include corrections for extraction efficiencies, dilution factors and blank contributions.

The L2000DX analyzer can be applied to other chlorinated pesticides or solvents, such as chlordane or trichloroethylene. Instructions for application to these chlorinated chemicals and conversion factors are also available and included in the instruction or handling manual.

A typical PCB analysis from a dielectric fluid takes about 5 min. The range of application is from 3 mg/kg to 2000 mg/kg (ETI, 2021 (accessed)-b).

For application on transformer fluids, no further sample preparation or clean-up is necessary other than collecting a clean (representative) sample. Introduction of any other source of chloride should be avoided (e.g., road salt).

Sample size is less than 5 mL (test tube must be filled with oil up to the 5 mL line of the tube). Samples should not be re-analysed. Pipettes and oils should be disposed of as PCB waste or organochlorine containing waste. The analysis solution typically can be disposed of as an ordinary aqueous waste containing nickel.

7.4.3 Reporting aspects if Party decides to accept these results as the final inventory

Results are read as being above or below the action level (in case of the test kit) per mass of hydraulic fluid (kg or g). The whole matrix for which the sample was representative will be assigned this result. If the result is above 50 mg/kg, the whole matrix mass will be assigned as PCB-contaminated and to be reported.

For the PCB analyzer, a concrete number is generated for PCB contamination, the whole matrix for which the sample was representative will be assigned this result: if the result is above 50 mg/kg, the whole matrix mass will be assigned as PCB-contaminated and to be reported.

It shall be noted that the equipment – besides the hydraulic fluid – is not covered by these test methods. When countries report the result, they should indicate if the final mass contains the equipment or not. The inventory format (Table 4) and the reporting format (Table 5) reflect this option.

7.5 Quantitative targeted analysis

The availability of accredited laboratories in countries which comply with the ISO/IEC 17025 standard ensures that analyses are undertaken competently in the respective matrix. The credibility of laboratory data that results from accreditation and especially from successful participation of the laboratory in interlaboratory assessments for PCB waste oils is important. To make results comparable, standardized methods should be used across country borders and time periods. Alternatively, other criteria can be used to check the quality of the reporting laboratory. The ultimate criterion would be the certificate for a successful participation in an interlaboratory assessment on PCB in dielectric fluids at concentrations around 50 mg/kg; not older than 3 [5] years.

For the purpose of the PCB inventory and national reporting, each is free to set its own criteria; but these should be recorded and provided.

PCB analysis includes several steps:

Step 1. Sample collection and storage

Care must be taken to assure that the sample collection follows quality assurance protocols and that equipment and containers are free from contamination. Most sample collections are by grab sampling.

Step 2. Extraction

PCB can be extracted by liquid-liquid extraction (LLE), with Soxhlet extraction and solid phase extraction (SPE). Purification from all the extracts can be performed on an Al_2O_3 column, followed by fractionation on an 1.5% (w/w) deactivated silica column and purification and/or an acidic silica column. Others include separatory funnel extraction or Soxhlet/Dean-Stark extraction.

PCB may be difficult to extract from oily matrices in which they are soluble. Some problems that may occur during extraction include evaporative losses during concentration, sorption onto labware, and contamination of samples.

Step 3. Clean-up

Clean-up steps are necessary to remove compounds that may interfere with the determination. Gel-permeation chromatography, silica gel, Florisil, or activated carbon is often used to remove matrix interferences.

Fractionation of PCB, such as to differentiate dioxin-like PCB (*non-ortho* substituted and *mono-ortho* substituted PCB) from indicator and other like PCB is not necessary for the PCB inventory under the Convention.

Step 4. Separation and Determination

The instrumental analysis of the cleaned extracts is carried out using a gas chromatograph coupled to an electron capture detector (GC-ECD) or a mass selective detector.
Capillary or high-resolution gas chromatographic (HRGC) columns are capable of separating the congeners of interest (indicator PCB, dioxin-like PCB, Aroclor mixtures); they are commercially available at different length and diameters.

For ECD detectors, which have high selectivity and sensitivity, a double column system should be applied to identify and quantify PCB compounds (already necessary for the 6 indicator PCB).

Mass spectrometers – either single or tandem - or ion-trap mass spectrometer (ITMS) detectors, which have somewhat lower sensitivity than ECD but greater selectivity for PCB can be used as well. High-resolution mass spectrometers (as sector-field instruments) have highest sensitivity and selectivity but are typically used for trace analysis.

The use of the more universal and less sensitive flame-ionization detector (FID) is not recommended.

7.5.1 Instrumental analysis using gas chromatography coupled to electron capture detection

7.5.1.1 EN 12766-1, EN 12766-2 and EN 12766-3

This European Standard was given the status of a national standard within the European Union member states at the latest by January 2002; conflicting national standards had to be withdrawn at the latest by January 2002. The Annexes A and B are normative. The standard is available for a fee. This European standard is one of a series of standards as listed as follows:

- EN 12766-1, Petroleum products and used oils - Determination of PCBs and related products: - Part 1: Separation and determination of selected PCB congeners by gas chromatography (GC) using an electron capture detector (ECD);
- EN 12766-2, Petroleum products and used oils - Determination of PCBs and related products: - Part 2: Calculation of polychlorinated biphenyl (PCB) content;
- EN 12766-3, Petroleum products and used oils - Determination of PCBs and related products: - Part 3: Determination and quantification of polychlorinated terphenyls (PCT) and polychlorinated benzyl toluenes (PCBT) content by gas chromatography (GC) using an electron capture detector (ECD).

Part 1 provides a European Standard that specifies a method to determine the concentration of up to 12 individual or defined unresolved small groups of polychlorinated biphenyl (PCB) congeners in petroleum products and related materials by means of a specified gas-chromatographic separation procedure. The gas chromatographic separation is valid for the different quantification procedures described in Part 2 of this European Standard.

This standard specifies two calculation procedures ("method A" and "method B") for PCB content. The basis for this quantification is taken from the chromatographic results of EN 12766-1:2000 in which all necessary experimental procedures are described for the specific analysis of unused, used and treated (e.g. dechlorinated) petroleum products including synthetic lubricating oils and mixtures of vegetable oils. The method is also applicable to petroleum products and synthetic lubricating oils suitably recovered from other materials, e.g. from waste materials. Both methods have different strengths and weaknesses which are described in the next paragraphs and which must be considered before use in a specific application. Proper application of either method A or method B needs to be carefully considered before use in a specific application.

Method A

Using method A, special care needs to be exercised to avoid interferences from non PCB substances which may occur in the chromatogram. Therefore, method A can be used predominantly for the analysis of used and unused insulating oils. It is recommended not to use calculation method A without special precautions for other than above-mentioned products. Calculation method A can produce two alternative sets of results, ‘All Probables’ and ‘All Possibles’. Therefore, care needs to be taken in order to interpret these results in the correct manner.

Method B

Method B uses as intermediate result the sum of six congeners, which belong to the most abundant in almost all technical PCB materials, thereby minimizing potential interferences from other (coeluting) non PCB substances. To obtain the PCB content, the intermediate sum from six congeners needs to be multiplied by a multiplication factor. Calculation Method B can be used predominantly for the analysis of liquids from used and waste materials of unknown origin and for samples with low PCB contents.

The six indicator PCB comprise the following congeners (see Table 9 and Figure 10):

Table 9: Indicator PCB

IUPAC Number	Chemical Name
PCB 28	2,2’,4-trichlorobiphenyl
PCB 52	2,2’,5,5’-tetrachlorobiphenyl
PCB 101	2,2’,4,5,5’-pentachlorobiphenyl
PCB 138	2,2’,3,4’,5,5’-hexachlorobiphenyl
PCB 153	2,2’,4,4’,5,5’-hexachlorobiphenyl
PCB 180	2,2’,3,4,4’,5,5’-heptachlorobiphenyl

Another method associated with the European waste oil directive is the **IEC 61619:1997** method 'Insulating liquids - Contamination by polychlorinated biphenyls (PCBs) - Method of determination by capillary column gas chromatography' (TC 10; price CHF 205). IEC 61619 specifies a method for the determination of polychlorinated biphenyl (PCB) concentration in non-halogenated insulating liquids by high-resolution capillary column gas chromatography using an electron capture detector (ECD). It gives total PCB content and maybe useful when a detailed analysis of PCB congeners is necessary).

It shall be noted that application of method 12766 quantifies the six indicator PCB, which on average constitute 20% of the total PCB (from measurements in technical materials). Therefore, for reporting the PCB content the amounts of the sum of the six indicator PCB have to be multiplied by the factor of 5 to obtain the 'total PCB' content.

7.5.1.2 USEPA Method 8082A Polychlorinated biphenyls (PCBs) by gas chromatography

This method may be used to determine the concentrations of polychlorinated biphenyls (PCBs) as Aroclors or as individual PCB congeners in extracts from solid, tissue, and aqueous matrices, using open-tubular, capillary columns with electron capture detectors (ECD) or electrolytic conductivity detectors (ELCD). Aroclors and individual PCB congeners have been determined by this method, using either a single - or dual column analysis system, and this method may be appropriate for additional congeners and Aroclors. The method also may be applied to other matrices such as oils and wipe samples, if appropriate sample extraction procedures are employed.

7.5.1.3 ASTM D4059 - 00(2018)

This is a gas-chromatographic method for the determination of PCB in insulating fluids. The standard needs to be purchased and is not available free-of-charge.

Quantification requires a peak-by-peak comparison of the chromatogram of an unknown specimen with that of standard Aroclor test specimens obtained under identical conditions. The technique is based on data for standard chromatograms of Aroclors 1242, 1254, and 1260 obtained using specific chromatographic column packing materials (mega-bore capillary columns) and operating conditions. The types and amounts of PCB associated with each peak have been determined by mass spectroscopy. The data given in the tables should not be used if chromatograms of the standards differ significantly from those shown in the figures. The peaks in such standard chromatograms shall be independently identified and quantified. Retention times are relative to *p*,*p*'-DDE = 100. Different isomers of PCB with the same number of chlorine substituents can cause substantially different responses from EC detectors. This technique is effective only when the standard PCB mixtures and those found in the unknown test specimen are closely related. Aroclors 1242, 1254, and 1260 are adequate standards because they have been found to be the most common PCB contaminant in electrical insulating oils.

This test method describes a quantitative determination of the concentration of polychlorinated biphenyls (PCB) in electrical insulating liquids by gas chromatography. It also applies to the determination of PCB present in mixtures known as askarels, used as electrical insulating liquids. This technique may not be applicable to the determination of PCB from other sources of contamination.

ASTM Method D4059-00 is used for determining PCB concentrations in various types of transformer oil using GC-ECD detection. The analyst must dilute transformer oil samples in a solvent prior to injection. The oil in the sample has been shown to quench the ECD. Calibration mixtures of PCBs in transformer oil must be prepared and diluted identically to eliminate the detector quenching bias resulting when samples are analyzed.

7.5.2 Instrumental analysis using gas chromatography coupled to mass selective detection

7.5.2.1 EPA 1668

This method determines chlorinated biphenyl congeners in environmental samples by isotope dilution and internal standard high-resolution gas chromatography/high-resolution mass spectrometry, HRGC/HRMS (USEPA, 2010). EPA developed this method for use in wastewater, surface water, soil, sediment, biosolids and tissue matrices. Other applications and matrices may be possible, which may or may not require modifications of sample preparation, chromatography, etc. thus, this method has quite universal and not especially developed for use on testing PCB containing equipment.

The PCB that can be determined by this method are the 12 polychlorinated biphenyls (PCB) designated as toxic by the World Health Organization (WHO): congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189 (van den Berg et al., 2006). The Method also determines the remaining 197 PCB, approximately 125 of which are resolved adequately on an SPB-octyl gas chromatographic column to be determined as individual congeners. The remaining approximately 70 congeners are determined as mixtures of isomers (co-elutions).

The 12 PCB designated as toxicity equivalency factor by WHO (also known as dioxin-like PCB or dl-PCB), and the earliest and latest eluted congener at each level of chlorination are determined by the isotope dilution quantitation technique; the remaining congeners are determined by the internal standard quantitation technique.

This method allows determination of the toxic equivalent for PCB (TEQ_{PCB}) for the dl-PCB in a sample using toxicity equivalency factors (TEFs; (van den Berg et al., 2006)) and allows unique determination of 19 of 21 PCB of interest to the National Oceanic and Atmospheric Administration (NOAA; (Lauenstein and Cantillo, 1998)). A second-column option is provided for resolution of the PCB 156 and PCB 157 congeners that are not resolved on the SPBoctyl column and for resolution of other PCB congeners.

This method also allows estimation of homolog totals by level of chlorination and estimation of sum of PCB (by addition of amounts from homologs) in a sample by summation of the concentrations of the PCB congeners and congener groups.

7.5.3 Reporting aspects if Party decides to accept these results as the final inventory

To be specified.

7.6 Codes to define the method of quantification

The following summarizes the analytical approaches for the quantification of PCB in equipment and assigns codes to these approaches. It is recommended to include these codes into the inventory format for documentation and consistency.

Table 10: Summary and codes for the analytical determination of PCB

Approach	Code	Information	Result	Quantification	Reporting
Reading from name plate	**R**				
	R1	PCB tradename		weight in kg	Total PCB
	R2	Year of manufacture		weight in kg	Total PCB
	R3	Cooling code		weight in kg	Total PCB
Density test	**D**	Phase upper or lower	Relative density	Lower phase indicates PCB > 50 mg/kg	Total PCB
Screening	**S**				
	S1	Clor-N-Oil	Adjusted numeric	Total PCB as above or below 50 mg/kg	Total PCB
	S2	L2000X	Adjusted numeric	Total PCB numeric	Total PCB
Confirmatory analysis	**A**				
	A1	Sum parameter	Aroclor pattern	Total PCB numeric	Total PCB
	A2	All PCB congeners		Sum of PCB numeric	Total PCB
	A3	6 indicator PCB	6 congeners	Sum of 6 PCB multiplied with 5	Total PCB

7.7 Implementation aspects

7.7.1 Selection of approach

National approaches should be defined and documented. It is recommended to take into consideration the following:

- Includes all permits to access, sample, report;

- Forms/templates (with the aim to be used for the national reporting and the inventory if subgroups are detailed):
    - For collection of information;
    - For assessment;
- Agreed procedures (and forms, formats) for maintaining and updating the inventory and report according to Article 6, Article 15 and in the national implementation plans (Article 7).

7.7.2 Responsible institution

- Design and sampling, includes identification/shortlist of owners or management entities that will be included in the inventory;
- Execution of the inventory (coordination and especially when desktop only);
- Laboratory/department, if subcontracted.

7.7.3 Analytical aspects

- Standard operational procedure for identification and quantification (needs to be clear, which approach is taken for each sector/type, etc.;
- Selection of analytical laboratory and method;
- Quality control;
- Reporting.

8 Appendix 1

8.1 Text reproduced from Annex A Part II

Annex A Part II of the Convention states a tiered approach as to the volumes and amounts of PCB present in equipment:

- Identify, label and remove from use equipment containing greater than 10 per cent polychlorinated biphenyls and volumes greater than 5 litres;
- Identify, label and remove from use equipment containing greater than 0.05 per cent polychlorinated biphenyls and volumes greater than 5 litres;
- Identify and remove from use equipment containing greater than 0.005 percent polychlorinated biphenyls and volumes greater than 0.05 litres.

8.2 Nameplates for transformers and capacitors

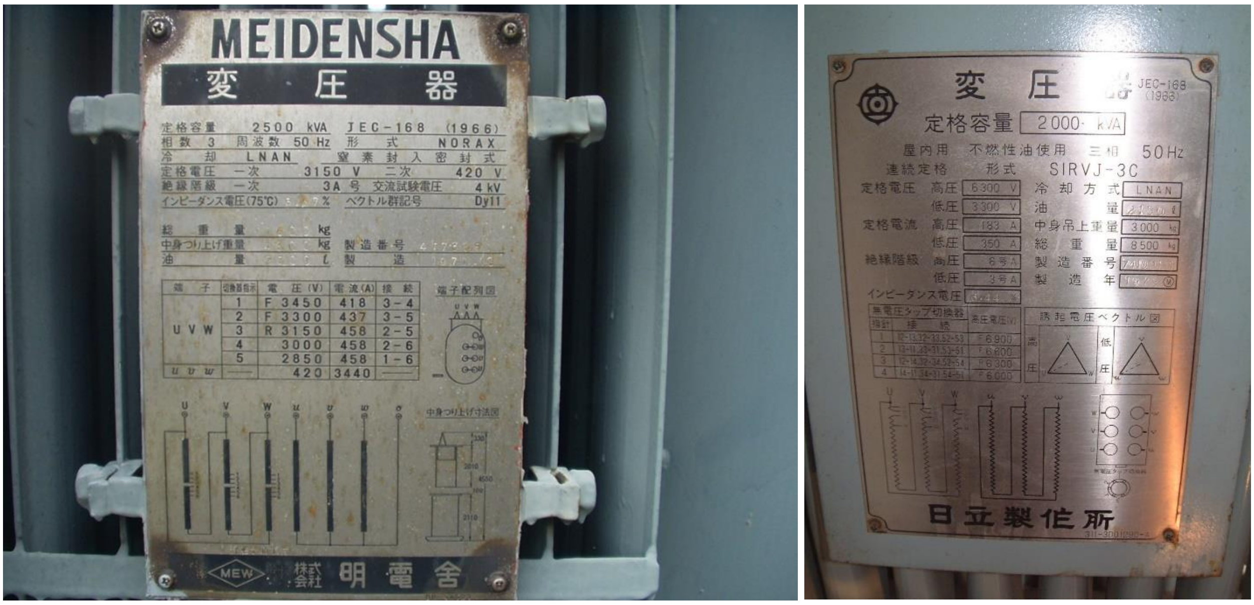


Figure 6: Japan: Nameplate of PCB-containing transformers with manufacturer, code, year (left) and year, weights (right)

8.3 Photographic impressions for PCB in open applications

The following is reproduced from PEN (PCB Elimination Network) booklets. Photos are courtesy of Urs K. Wagner of ETI Environmental Technology Ltd., Chur, Switzerland.

8.3.1 PCB in public and residential buildings

Figure 7: PCB in public and residential buildings – Indoor environments

Figure 8: PCB in public and residential buildings – Outdoor environments

8.3.2 PCB in machinery and installations

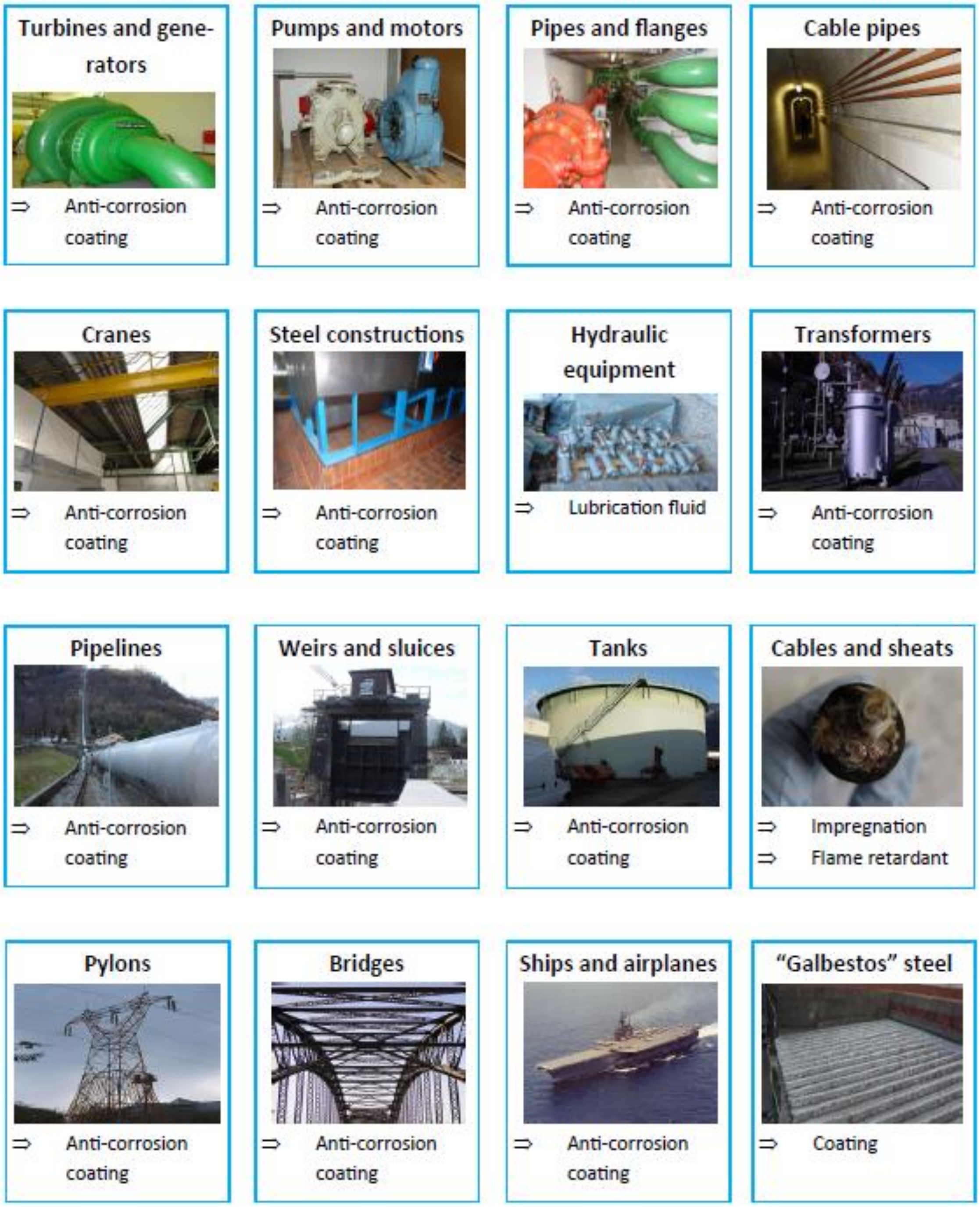


Figure 9: PCB in materials and installations

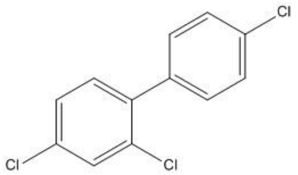
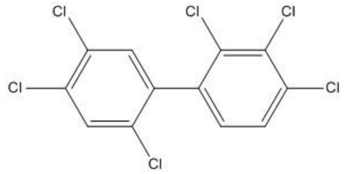
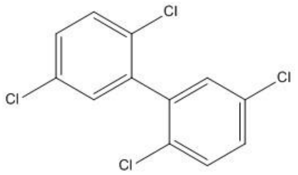
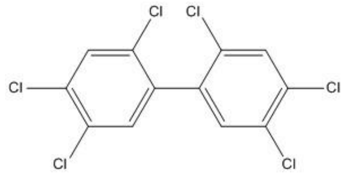
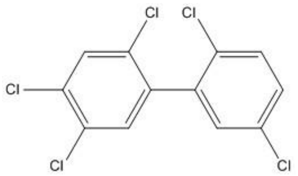
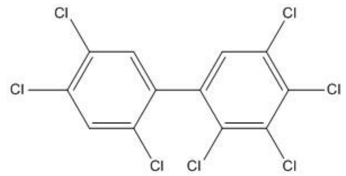
PCB 28 2,4,4'- Trichlorobiphenyl 	PCB 138 2,2',3,4,4',5'- Hexachlorobiphenyl 
PCB 52 2,2',5,5'- Tetrachlorobiphenyl 	PCB 153 2,2',4,4',5,5'- Hexachlorobiphenyl 
PCB 101 2,2',4,5,5'- Pentachlorobiphenyl 	PCB 180 2,2',3,4,4',5,5'- Heptachlorobiphenyl 

Figure 10:IUPAC number, name, structural formulae of the six indicator PCB

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