

Management of PCBs from Open and Closed Applications – Case Study Switzerland

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1 Background and Objectives

Polychlorinated Biphenyls (PCBs) are one of the most common and widely dispersed persistent organic pollutants (POPs). PCBs can have serious health and environmental effects, which can include carcinogenicity, reproductive impairment, immune system disruption and, by effects on wildlife, a loss of biological diversity [1, 2, 3, 4]. Most PCBs were manufactured by several companies in various industrialised countries mainly in the Northern Hemisphere. It is estimated that the total production was approximately 1.3 million tonnes of which 48% of PCBs were used for transformer oil; ca. 21% for small capacitors; 10% for other ‘nominally closed’ systems such as heat transfer systems and hydraulic systems, particularly in mining equipment; and approximately 21% for open uses [5]. Open and partially open applications included e.g. caulks/sealants (Figure 1), paints (Figure 2), plasticisers, anti-corrosion coatings, copy paper and flame retardants (Table 1). The large share was used in buildings and other constructions.

According to *Annex A part II* of the Stockholm Convention, Parties to the Convention are obliged to eliminate electrical equipment and oils containing PCBs from use by 2025 and to manage them using environmentally sound waste management by 2028¹. Therefore PCB inventories prepared for the Stockholm Convention focus mainly on the closed applications such as PCB-containing transformers and capacitors (see paragraph 4 below) (*Stockholm Convention PCB*). However, *Annex A, Part II (f)* of the Stockholm Convention requires that efforts should be made to identify other articles containing more than 0.005% PCBs including uses in open applications and to manage them in an environmentally sound manner in accordance with paragraph 1 of Article 6. Apart from this requirement of

the *Stockholm Convention*, the handling, remediation, removal and disposal of PCB uses in open applications of PCBs are not yet regulated by any international guidelines despite their high relevance for human and environmental exposure. Due to the lack of regulations and awareness obsolete turbines, generators, power aggregates etc. painted with PCB (Figure 2) are often labelled as being re-usable and are therefore outside the scope of the Basel Convention. Article 6(1) (d)(iii) of the Stockholm Convention which requires that upon becoming wastes articles are not permitted to be subjected to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of persistent organic pollutants needs to be applied more stringently. This fact sheet therefore focuses on PCBs in open applications as these uses have been given relatively little attention by most countries.

Since current PCB inventory activities under the Stockholm Convention focus mainly on the closed applications the situation on PCB inventory and management of closed systems is described briefly in chapter 4 and links to related guidance papers and technical reports in chapter 5.

The remediation and management of PCBs in open applications is important because of the relatively high levels of human exposure and environmental releases compared to closed systems and their associated health effects. Although open uses accounted for only approx 21% of the total production it is estimated that approximately 50% of the total PCB emissions have come from these ‘open system’ uses [5]. Long-term exposure to even small concentrations can have adverse effects on human health, especially on the unborn child [6] [7].

Caulks/Sealants (buildings, bridges); rubber seals; gasket sealers	Lubricating fluid in oils and grease; cutting oils
Paints and plaster (buildings, construction, swimming pools, machinery)	PCBs as flame retardant and impregnating agent (e.g. indoor wood sealing for panels and floor finishes [17])
Anti-corrosion coatings (indoors and outdoors)	Adhesives
Sealed double glazing windows (e.g. in Norway)	Carbonless copy paper
Surface coatings (for example floors)	Pesticide extenders
Cables and cable sheaths	Inks

Table 1: Some open applications of PCBs

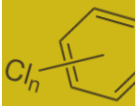


Figure 1: PCB containing caulk (sealant) in façade
(Source: ETI)

PCBs from open applications diffuse into the environment and other surrounding materials. PCBs in caulks/sealants used in housing/construction (Figure 1), for example, can contaminate the surrounding soil [8] and building materials such as concrete or wood. Furthermore PCBs in open applications in housing are released directly into the indoor environment [9] [10]. A building in Sweden, for example, was calculated to release 0.07 % of the total PCB content of the sealants each year². Concentrations in indoor air vary greatly depend on the type of PCB application and the technical PCBs mixtures used as well as temperatures and ventilation [12]. PCB levels in indoor air may consequently be hundreds of times higher in buildings with sealants containing PCBs. And concentrations up to 6000 ng/m³ have been measured in the indoor air of some office buildings with PCB-contaminated sealants [13]. Whilst concentrations in homes are normally lower than in offices household contamination results in elevated levels of PCBs – particularly the more volatile congeners – in the blood of residents [14, 15]. Buildings frequented by many people (schools, hospitals, etc.) or with long duration of stay (residential housing; working environment) pose the greatest risks for the users. The WHO TDI is 20 ng PCB/kg body weight/day [16] and so the indoor limit for 24 hour exposure should be an indoor concentration of less than³ 60 ng/m³. This is considerable lower than the PCB indoor limits in most industrial countries which were often derived from the former TDI of 1000 ng PCB/kg body weight/day. The urgency to adopt lower indoor concentrations has been increased given that PCBs have recently been classified as a Class 1 Carcinogen by the International Agency for Research on Cancer (IARC) [4].

Some European countries and the US have been tackling the more complex problem of open systems of PCBs for several years with Norway, Finland, Sweden and Switzerland having the most comprehensive management strategies for PCBs in open applications.

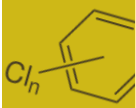
PCBs were used in open applications between the



Figure 2: PCB containing anti-corrosion coating on a turbine
(Source ETI)

1950s and the 1970s (in some countries until early 1980s). The period over which PCBs were used in different applications varied between countries depending on production, use and legislation. It was previously believed that products like PCB containing caulks/sealants (Figure 1) and coatings had not been exported to developing countries because they were rather expensive. It is now recognised that PCB usage has been worldwide due to development aid projects.

In order to establish a PCB inventory the historic usage in a country/region needs to be evaluated as a first step to determining a management strategy and prioritising further actions. Most PCB use in open applications has been in those industrial countries with major construction and development activities between the 1950s and early 1980s – with main use in buildings constructed between about 1965 and 1975 [13]. The largest open application of PCB has been caulks/sealants (Figure 1) and paints in buildings and other construction such as swimming pools (paint or sealants), metal pipes or machinery (Figure 2). It is estimated that approximately half of the buildings constructed in Switzerland and the US over this period have been contaminated by PCBs and that some of these buildings contain hundreds of kilograms of PCB [18] [13]. Sealants and industrial paints have long operational lifetimes of perhaps 40 to 60 years and are now becoming increasingly relevant in demolition projects. If caulks/sealants or paints are not professionally removed during demolition then the site and surrounding land can become seriously contaminated. Furthermore debris/rubble and related recycling materials can also be contaminated resulting in PCB contamination and release in the further recycling, re-use and disposal of these materials. The use of contaminated construction materials (in particular sealants and paints) has resulted in the contamination of farms and their animals (e.g. chicken, cows and sheep). This becomes more important as steps are taken to move towards a closed cycle economy [19] with the increased importance of “urban mining” and re-use of wastes in future.



Today renovation of building shells is very popular and often supported by governments [20]. Buildings are here often renovated with high insulation standards in order to minimize energy loss. As an economy measure the insulation is often simply fixed on the existing façade in which case PCBs from the sealants and paints penetrate into the new insulation with reduced emission into the environment. This has, however, resulted in increased indoor contamination after renovation. During renovation of PCB containing buildings, cross-contamination can occur and large quantities of PCBs can be released to air and then spread to other parts of the building and the surroundings. Handling, removal and disposal of building materials containing PCBs during remediation or renovation activities poses a particularly high risk of exposure if the work is not undertaken by remediation companies experienced in such PCB removal.

The scrapping of metal (e.g. electric poles and pipes) coated with PCB paints and the further treatment of the steel scrap in electric arc furnaces is a contemporary source of PCB release. Furthermore highly toxic polychlorinated dibenzofurans (PCDF) are present in PCB formulations. PCDF are formed and released from thermal treatment of PCBs such as fires/combustion [21] [22], pyrolysis [23] or other thermal treatments [24]. This need to be considered in the demolition pro-

cess particularly, for example, where flame cutting is used for breaking up PCB coated materials.

Partly as a result of the failure of the Stockholm Convention to require inventories of open-uses of PCBs final disposal and treatment is generally not well regulated. Indeed PCB wastes from uses in open applications are often not recognized as hazardous waste at the time of disposal even in countries which are aware of the presence of PCB in open application. Therefore PCBs can also escape into the environment at the end-of-life by inappropriate treatment of the materials during demolition and the final disposal in unsuitable landfill sites.

The problem of PCBs in open applications is yet to be recognised by many countries. Many industrial countries completed their inventories of PCBs capacitors and transformers years ago but have yet to start investigating PCBs in open systems; Other countries focus only on one specific application, for example caulk/sealants, and ignore the impact of other open uses of PCBs.

The experiences from countries which have made efforts to address PCBs in open applications are therefore valuable for those countries just starting to tackle this challenging issue.

2 Approach, Achievements and Results

Switzerland is one of the leading countries in PCB management. Experiences in Switzerland show that many public buildings, constructed or renovated between 1955 and 1983, often contain PCBs in their elastic sealants, paint applications, cables and cable sheaths or anti-corrosion coatings. Another important source of a potential PCBs contamination are electrical ballasts. Such ballasts can work for 50 to 60 years and are often still in use but leakage and failure rates and increases drastically as they age. This can result the ballast/capacitor exploding and releasing PCBs [25].

In 1999/2000, caulk and sealant samples were taken from public buildings and school buildings in various Swiss cities. After publication of the results in a Swiss consumer magazine in 2001, efforts were undertaken by a national task force to address the problem on a national scale. It was estimated that between 50 and 150 t of PCB were present in joint sealants in buildings in Switzerland, 150 to 600 t of PCB in buildings in Sweden [26] and 20,000 t of PCB in sealants in buildings in Germany [27].

In 2003 the *Swiss Federal Office for the Environment* published a directive requiring investigations about the PCBs content in buildings constructed between 1955 and 1983, calling for special measures to protect wor-

kers and the environment. The thresholds were set at 50 mg/kg of PCBs in caulk and, based on the former tolerable daily intake (TDI) of 1 µg of PCB per kg bodyweight per day, an average concentration over one year (indoor air measurements in summer and winter) of more than 6000 ng PCB per m³ indoor air (rooms with eight hours per day occupancy such as offices and public buildings) and 2000 ng PCB per m³ indoor air (homes, hospitals and permanent residence). However, considering the updated WHO TDI (20 ng PCB per kg bodyweight per day) the indoor air levels for 24 hour exposure should be below 60 ng PCB per m³.

The *Swiss Ordinance on Construction Works (BauAV)* and, from 2015 on, the updated edition of the *Technical Ordinance on Wastes (TVA)* – require a screening and analysis before a building is renovated or demolished. Such screenings and analyses often reveal the presence of PCB applications – and other pollutants like Asbestos, PAH, short chain chlorinated paraffin, flame retardants and others.

Since the publication of the PCB directive in 2003, PCB screenings in buildings and consequently their remediation (Figure 3 and 4) have increased significantly – at least in the public sector. A professional and environmentally sound remediation of a building requires ca-

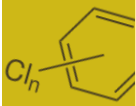


Figure 3: Removal of PCBs caulks in a Clean up Zone in a residential building (Source ETI)

reful planning and investigation together with appropriate techniques and achievable, sustainable clean-up targets. The work must be carried out by skilled and reliable specialists both for the remediation as well as the supervision of the works.

Appropriate decontamination, cleaning and removal techniques with associated precautions for environment and workers have been developed. As there have been numerous complex PCB remediation projects in Switzerland, different approaches and techniques are constantly being developed, tested, adapted and improved. Thus even the most current guidelines cannot be considered final or complete.



Figure 5: Decontamination of PCBs coating by high pressure water method (Source: ETI)



Figure 4: Removal of PCBs surface coating in industrial plant (Source ETI)

Depending on the type of application and the concentration of PCBs, appropriate removal techniques must be defined (ideally by a specialist company) and applied: Caulks containing PCBs for example are often removed and eliminated together with the caulk concrete edges (Figure 3). This method allows the concrete to be cut in the uncontaminated areas. On the other hand, plant and equipment treated with PCBs anti-corrosion coatings are often better dismantled (without generating heat and diffusing dust and particles) and then decontaminated by high-pressure water methods in a licensed off-site plant (Figure 5 and 6).



Figure 6: Decontamination of PCBs coating by high pressure water method (Source: ETI)

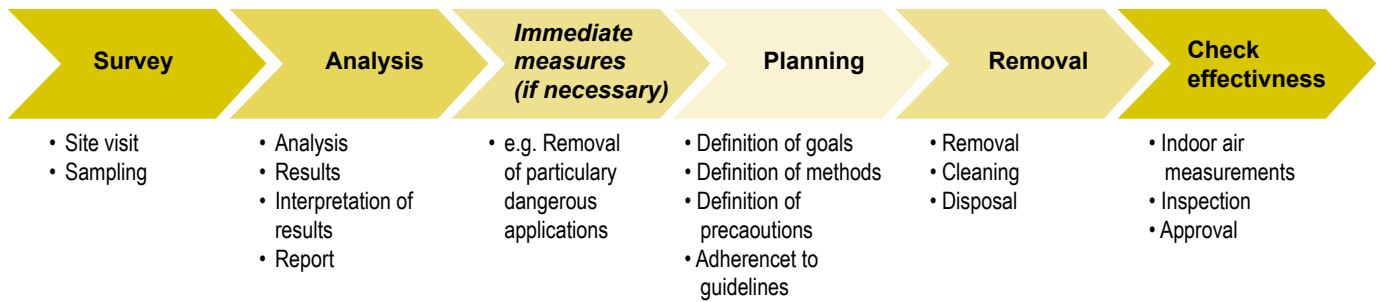
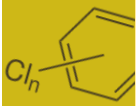


Figure 7: Step-by-step approach of PCB remediation in open applications

PCB remediation and waste management experience show that only a step-by-step approach and careful planning will guarantee a sustainable removal and disposal of PCBs containing materials (Figure 7).

It must be ensured that only qualified contractors are allowed to remove materials which are highly contaminated by PCBs. In these cases it is essential that the work is clearly defined and that there is adequate supervision of workers together with appropriate precautions for the protection of the environment.

When handling, cutting, removing and decontaminating materials containing PCBs, it must always be recognised that highly-toxic polychlorinated dibenzofurans can be formed and released when heat is generated and appropriate precautions must be taken.

Where PCBs have been removed, indoor air measurements must be carried out before the rooms are used again. Only sampling will allow an assessment of the

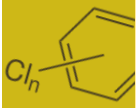
effectiveness of the remediation work and ensure that the residual concentration in the indoor air is acceptable. In Switzerland, there is no defined threshold for maximum PCB concentration in indoor air after PCB remediation activities. Thus, some Swiss cantons currently refer to the Guideline of the German Federal State Northrhine-Westphalia and set the threshold at 300 ng/m³ ± 100% tolerance, resulting in a maximum indoor air concentration after a PCB clean-up of ≤ 600 ng/m³. Today this is approximately 10 times above the levels to meet the revised WHO TDI of 20 ng PCB per kg bodyweight per day (considering 24 hours exposure).

PCBs wastes with a concentration of greater than 50 mg/kg (or at levels defined by specific country limits if lower than this) should be disposed of as hazardous wastes and destroyed or irreversibly transformed in for example, approved high-temperature incineration plants or non-combustion facilities.

3 Conclusions and Lessons Learnt in Managing PCBs in Open Applications

The conclusions and lessons learnt on managing PCB in open application from Swiss projects and experience can be summarised as follows:

- As a first step it is necessary to undertake an assessment of whether PCBs have been used in open applications in the country/region. For Switzerland and other investigated countries the largest uses of PCBs in open applications have been in sealants and paints.
- All open PCBs applications should be addressed within a comprehensive management framework.
- In order to manage all applications of PCBs in an environmentally sound manner, a legislative framework should be established which requires the investigation and remediation of PCB containing materials and stipulates concentration thresholds for both solid materials and indoor air quality.
- PCB removal techniques and associated precautions should be regulated in a national PCB framework. Different applications need different remediation approaches and this can be addressed in associated guidance.
- Standards for screening, sampling and analysis are necessary for the assessment of existing contamination, for the remediation and for the assessment of the effectiveness of the remediation.
- After PCB remediation or removal works, indoor air quality measurements should be undertaken to assess the effectiveness of the remediation, as part of the works approval process.
- Remediation and removal of PCB materials must only be carried out by appropriately qualified and experienced specialist contractors. This work must always be supervised by experts.



4 Current Situation of Closed Systems of PCBs

According to Annex A part II of the Stockholm Convention, Parties to the Convention are obliged to eliminate PCBs used in closed systems such as transformers and capacitors as well as oils containing PCBs by 2025 and manage these in an environmentally sound management by 2028.

In most industrial countries PCBs contained in equipment have been inventoried and eliminated over the past three decades. In Switzerland, for example, the first inventory of PCBs in electrical equipment started in 1983, and by August 1998 all PCB containing equipment had been eliminated.

Most of the Parties to the Stockholm Convention have also compiled preliminary PCB inventories for their National Implementation Plans (NIP). This has revealed that approximately 3 million tonnes of equipment containing or contaminated with PCBs is still in use in developing and transition countries [28, 29].

However, different methods and approaches to inventories have been used. Some countries simply estimated the number of devices suspected to contain PCBs; some calculated the weight of PCBs containing waste based on the (often poor) feedback from questionnaires; while others focussed not only on transformers and capacitors but also analysed samples from sites suspected to be contaminated. Assessments of the real situation in the countries show that the actual quantities of PCBs often vary significantly from the preliminary assumptions and the inventory data. Fortunately, the actual quantities of PCBs are not necessarily higher than those which had been estimated. Country inventories estimated the PCB stockpiles to include 6 million tonnes of contaminated oil and equipment and this was then corrected to the 3 million tonnes noted above. The quality and status of PCBs inventories is therefore a fundamental consideration [28].

Reliable detection, identification and quantification are the starting points for efforts to remove PCB contamination from electrical equipment and open-use applications. In order to decide the environmentally preferred

and most economically viable elimination or treatment options for a specific country it is necessary to first collect reliable information about the kind and the extent of the PCBs problem.

The management of PCBs varies greatly between countries and regions but it has been demonstrated in many Western, Asian, Pacific, African Central and Latin American Countries, that the effective integration of field screening methods into the inventory process can deliver substantial cost savings in later project stages. The faster and more reliably contamination is discovered, the sooner any damaging leakage and associated contamination can be stopped and the earlier clean-up and disposal can begin.

The logistical and financial burden for a safe and environmentally sound PCB elimination programme is high and this presents particular challenges for developing countries. The ten years experience of implementing the Stockholm Convention's PCB inventory, monitoring and management projects have shown the scale of the challenge but has also provided some examples of best practice.

After over 10 years of Stockholm Convention implementation only a small fraction of the 3 million tonnes of PCB containing equipment has yet been managed. There is still a very long way to go to achieve the 2025/2028 aims.

The difficulties are similar to those met when dealing with POPs pesticide stockpiles and other legacy POPs and therefore will be a challenge for the hundreds of POP-like organohalogen compounds in use today⁴ and which can present an intractable problem for developing countries – due to their limited resources and lack of appropriate destruction capacity. Extended producer/user responsibility and chemical substitution is ultimately inevitable if these countries are to protect human health and the environment whilst meeting their mid to long-term sustainable production and consumption needs [31].

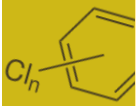
5 Guidance and Information Materials Available

General international information on PCB and PCB management

- Stockholm Convention [Guidance documents on PCBs](#) (mainly closed applications)
- UNEP (1999) [Guidelines for the Identification of PCBs and Materials Containing PCBs](#)
- European Commission. [Polychlorinated biphenyls and polychlorinated terphenyls \(PCBs/PCTs\)](#)
- GIZ Film [“PCBs under control!”](#)
- HELCOM: [Polychlorinated Biphenyls](#)
- PCBs Elimination Network (PEN) [\[website\]](#)

Guidances on open PCB applications

- US EPA: [PCBs in Caulk in Older Buildings](#)



- US EPA: [Polychlorinated Biphenyls \(PCBs\)](#)

Guidances on open PCB applications from Switzerland (in German)

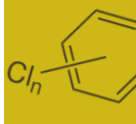
- BAFU [Richtlinie PCB-haltige Fugendichtungsmassen](#)
- BAFU [Konzept Korrosionsschutz im Freien](#)
- BAFU [Planungsgrundlagen Umweltschutz bei Korrosionsschutzarbeiten](#)
- BAFU [Praxishilfe PCB-Emissionen beim Korrosionsschutz](#)
- KBOB-Empfehlung „[PCB in Fugendichtungsmassen](#)“

Guidances for identification, management and destruction of PCB

- Basel Convention [Destruction and decontamination technologies for PCBs and other POPs wastes](#)
- Basel Convention [A training manual for hazardous waste project managers](#)
- UNEP Chemicals [Guidelines for the identification of PCBs and materials containing PCBs](#)
- UNEP Chemicals [Inventory of World-wide PCB Destruction Capacity](#)
- UNEP Chemicals [PCB Transformers & Capacitors - From Management to Reclassification and Disposal](#)
- IHPA [Provisional POPs Technology Specification and Data Sheets Secretariat of the Basel Convention](#)
- STAP [Selection of POP Disposal Technology for the Global Environment Facility](#)
- UNEP Chemicals <http://www.chem.unep.ch/Publications/pdf/SurvCurrAvNIncPCBDestrTech.pdf>
- Basel Convention [Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants \(POPs\)](#)
- Basel Convention [Updated technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls \(PCBs\), polychlorinated terphenyls \(PCTs\) or polybrominated biphenyls \(PBBs\)](#)
- Stockholm Convention (unintentionally produced PCBs) [Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C](#)

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1 The PCBs Elimination Network (PEN) was launched in 2010 as an arrangement for global information exchange on the promotion of the cost-effective completion of the environmentally sound management (ESM) of PCBs. While PCB oils and electrical equipment containing or contaminated with PCBs (closed systems) are the main focus of PEN the expert group has started to consider also open PCB applications.

2 60 g PCBs were annually released from a building containing 90 kg PCB in sealants [11]

3 Given that everybody is exposed to PCBs from other sources as well as from indoor exposure

4 A recent screening of the approximately 93,000 chemicals currently in use has estimated that between 190 and 1200 chemicals are potential POPs [30].