SOURCE ACTIVITY TITLE: SOURCES OF POYCHLORINATED BIPHENYLS EMISSIONS

NOSE CODE: N/A

NFR CODE: N/A

Introduction

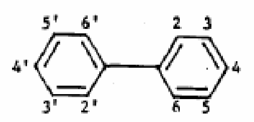
This model chapter is aimed at summarizing information relevant to polychlorinated biphenyls emissions for the purposes of their inventory.

1. GENERAL

1.1 Definitions

Polychlorinated biphenyls (PCBs) – a group of synthetic organic chemicals known as chlorinated hydrocarbons which include any chemical substance of the biphenyl molecule that has been chlorinated to varying degrees. The chemical formula for PCBs can be represented as $C_{12}H_{(10-n)}Cl_n$, where n is the number of chlorine atoms within the range of 1–10. A total of 209 individual isomers (or "congeners") exist. The term "homologue" is used to refer to all PCBs with the same number of chlorine (e.g. trichlorobiphenyls). Homologues with different substitution patterns are referred to as isomers. For example, dichlorobiphenyl homologue contains 12 isomers. The sum of PCBs may sometimes refer to the sum of seven individual PCB isomers (congeners) called the "Dutch seven". These are commonly reported as ΣPCB_7 and includes PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, PCB-153 and PCB-180. For transparency, it is good practice to report the specific isomers referred to when reporting sum PCBs.

1.2 Properties



PCBs have high heat capacity, low conductance, they are inert to acids and alkali, have good solubility in fats, oils and organic solvents, and are explosion-proof. As chlorine content increases, PCBs state of aggregation also changes as well as other properties including their stability in the environment (Table 1.1). With chlorine content from 19 to 43 %, the products have a crystalline form, 43–56 % – oil-shaped, 57–69 % – semisolid and resin-shaped, and from 67 to 70 % - crystalline again.

Table 1.1 PCBs physical and chemical properties

Compound	CAS number	Formula	Molecular weight	Number of isomers
Monochlorobiphenyls	27323-18-82	$C_{12}H_9Cl$	189.0	3
Dichlorobiphenyls	25512-42-9	$C_{12}H_8Cl_2$	233.1	12
Trichlorobiphenyls	25323-68-6	$C_{12}H_7Cl_3$	257.5	24
Tetrachlorobiphenyls	26914-33-0	$C_{12}H_6Cl_4$	292	42
Pentachlorobiphenyls	25429-29-2	$C_{12}H_5Cl_5$	326	46
Hexachlorobiphenyls	26601-64-9	$C_{12}H_4Cl_6$	361	42
Heptachlorobiphenyl	28655-71-2	$C_{12}H_3Cl_7$	395.3	24
Octachlorobiphenyls	31472-83-0	$C_{12}H_2Cl_8$	430.0	12
Nonachlorbiphenyls	53742-83-0	$C_{12}HCl_9$	464.2	3
Decachlorbiphenyls	2051-24-3	$C_{12}Cl_{10}$	498.6	1

The number and position of chlorine molecules attached to biphenyl affect the toxicity of individual PCBs. Some PCBs (coplanar PCBs) have been identified as “dioxin-like” with relative toxicities 100–1000 times higher than those associated with others PCB congeners. These PCBs just like dioxins/furans have got toxic equivalency factors (TEFs).

PCBs are only sparingly soluble in water. Their solubility in water decreases as chlorinity increases (e.g. monochlorobiphenyl solubility is 5.9 mg/l, and that of decachlorobiphenyl – 0.015 mg/l). PCB's volatility also decreases as chlorinity increases.
Industrial PCBs are colorless or yellowish viscous liquids with boiling point from 325 to 390^{o}C and congelation point up to 30–70^{o}C below zero. Chlorine content ranges from 42 to 54 % mass.

1.3 PCBs production and use

The total global production of PCBs between 1930 and 1993 has been estimated to be 1.324 million tones (Brevik et al., 2002a).

PCBs were used both for nominally closed applications (e.g., capacitor and transformers, heat transfer and hydraulic fluids) and in open-end applications (e.g., flame retardants, inks, adhesives, microencapsulation of dyes for carbonless duplicating paper, paints, pesticide extenders, plasticizers, polyolefin catalyst carriers, slide-mounting mediums for microscopes, surface coatings, wire insulators and metal coatings (Toxicological Profile…, 2000).

The main use of PCBs has been as dielectric insulating material in electrical equipment such as capacitors and transformers (see the Chapter PCPB of the Guidebook).

2. SOURCES OF PCBs

The main sources of PCBs emission into the environment can be divided into 5 groups:

1) production of PCBs and products (equipment) containing PCBs;
2) use of products containing PCBs;
3) utilization of PCBs and materials containing PCBs;
4) emission from reservoirs polluted by PCBs;
5) thermal processes.

In most countries, commercial PCBs and products containing PCBs are no longer produced anymore. But for the retrospective consideration of emission, this group is important. For example, it is known that in the production of capacitors PCB losses reached to10–20 % of dielectric used for filling.

The second group (PCB usage) is vast and heterogeneous. Polychlorinated biphenyls had and partially still have various applications in closed systems (such as dielectric liquids in capacitors and transformers, in hydraulic and cooling equipment, cables) and as peptizers for paper impregnation, paints manufacture, etc.

The third group of sources includes various PCB-containing wastes, worked out equipment and materials that are eventually recycled or removed into dumps.

Another source category includes contaminated soils, bottom sediments, waters that act as secondary sources of PCB emissions.

Emissions can also be expected from various thermal processes. These are processes where PCBs are synthesized like dioxins: the forming of PCBs as a by-product is possible in any chemical process involving chloride and organic carbon, or emitted due to incomplete combustion of PCB impurity in fuel (raw material).
The European PCBs emission inventory for 1990 (Berdowski et al., 1997) enumerates the following sources: coal combustion, steel smelting (open-hearth, converter, electric), sintering, waste incineration, electrical equipment (capacitors and transformers).

3. CONTRIBUTION TO EMISSION

Electrical equipment is the most important usage category of PCBs. Respectively PCBs in electrical equipment are potentially the greatest source of environmental pollution by PCBs due to leaks from operating installations, installations at storage or disposal and they are considered as a priority source of environment pollution by PCBs in several emission inventories. In the UK, for example, by the estimates of APARG (1995), over 90 % of PCB emissions originated from transformers and capacitors leaks and from fragmentizing operations. The European emissions estimates for 1990 (Berdowski et al., 1997) indicate that as much as 94 % of PCB emissions originate from this source. It should be kept in mind that PCB emission estimates from electrical equipment (and from other closed applications) are highly uncertain; this also valid for open application of PCBs; some emission inventories did not even include these sources of PCBs. Thus during PCBs inventory in the USA open and closed application of PCBs were not taken into account; it was stated that the main contributor to PCBs emission is the waste incineration (municipal waste combustion, hazardous waste incineration, and medical waste incineration contribute to over 95 % of national PCB emissions). Municipal waste combustion contributes to 51 %, medical waste – to 26 % and hazardous waste incineration – to 18 % (1990 Emission Inventory…, 1998).

Comment [kbr1]: The latter part of this sentence is unclear and needs to be rephrased. E.g. "It should be kept in mind that PCB emission estimates from electrical equipment are highly uncertain. Secondly, some emission inventories did not even include this source of PCBs.

According to the results of PCBs emission inventory in Belarus secondary metal smelting is the main source of atmospheric emissions of PCBs (about 90 %); emissions from electrical equipment and other applications of PCBs were not taken into account in the recent inventory.

4. ABATEMENT

Taking into consideration heterogeneity of PCBs pathways (products, leaks, in-stack emission etc.) prevention of PCBs discharges into the environment can be fulfilled with the help of different strategies:
a) safe application of PCBs (including management labeling, limitations on usage etc.);
b) safe disposal of PCBs (inventory, prevention of leaks, leaks cleaning, labeling, special containers and landfills etc.);
c) complete distruction of PCBs (vast list of technological measures mostly aimed at high level of destruction and removal of PCBs from PCB wastes);

d) PCBs emission control from thermal processes. Due to low levels of PCBs in waste gases from most of processes special measures are not proposed: PCBs emissions can be controlled generally like other chlorinated compounds in emissions, especially dioxins/furans: regulation of combustion time and themperature, temperature in cleaning devices, sorbents application etc.

5. METHODOLOGY

A simpler methodology is based on application of aggregated emission factors and production statistics. PCB emissions are calculated by the formula:

PCBs emission = emission factor x production output (fuel or wastes combusted).

A more reliable methodology is based on emission factors for specific processes, taking into account data on the type and efficiency of control equipment, and the content of PCBs in raw materials, fuels and wastes.

However these traditional methodologies can be applied mainly for in-stack PCBs emission, i.e. for thermal processes. For other sources, including open and closed applications, reservoirs simple emission factors can be proposed, but they are very uncertain and in most cases demand statistical data which is not available (first of all PCBs inventory is necessary).

A detailed methodology to estimate PCBs emission is based on measurements of a certain source or selected sources from a source category. For emission assessment from open and closed applications and reservoirs modeling should be applied taking into account rate of leaks and volumes of PCBs leaked, properties of soils and surfaces, climate conditions etc.

6. ACTIVITY STATISTICS

Data on the industrial production and fuel combustion, which are minor sources of PCBs is available from national statistical reports. Data on scrap reclamation, wastes incineration, use of PCBs for some open applications (paints, dyers etc.) and some other sources can be obtained from industry associations and enterprises. This information is usually satisfactory for estimation of emissions with the use of the simpler methodology. However, in most cases, no data are available from the statistics on such major sources as electrical equipment with PCBs, PCBs landfilling. In these cases special studies (e.g. PCBs inventory) or some expert estimates are necessary.

The application of the detailed estimation methodology may be complicated unless the statistical data are available directly from the given plant.

Data on PCBs content in soils, bottom sediments and wastes, wastes amount and density, air temperature, precipitation, etc. are necessary for evaluation of PCBs emissions from contaminated reservoirs. At present, many of these parameters are out of public knowledge, since field studies and measurements available are rather limited.

7. POINT SOURCE CRITERIA

Steel ferrous metal plants, production of PCBs and PCB-containing products and equipment, plants and places where large amounts of equipment with PCBs are installed, as well as PCBs utilization plants can be considered as large point sources.

8. EMISSION FACTORS

This chapter gives emission factors by source categories. It mainly includes tables with short descriptions. This section does not consider electrical equipment as PCBs release and emission source; it is described in the Chapter B651 of the Guidebook.

Because PCBs emission should be reported as total PCBs emission factors are given in the tables as a sum of PCBs congeners. It should be taken into account that different analytical procedures are used; so the term "sum of PCBs" in most cases does not always mean sum of all individual PCB congeners.

In some papers (for instance Lee et. al., 2005) emission of PCBs is calculated also as Σ TEQ (toxic equivalency) according to TEFs of individual congeners, but this approach is hardly to be used as a common practice at the modern level of knowledge of PCBs emission.

Fuel Combustion

PCBs are likely to be emitted in small amounts during fuels (first of all coal and residual oil) combustion, though data available on PCBs emission from these sources content is rather scarce. There are evidences, that emissions of PCBs are affected by fuel contamination with PCBs. According to Lee et. al.(2005), level of PCBs content in emission depends on chlorine content in fuel, so PCBs emission from hard coal is 10-15 times higher than from firewood.

In (Technical Paper..., 1995) the following emission factors are recommend: for coal and oil – 3.6 mg/t, for firewood – 3.5 mg/t; the factors specified are taken as equal for all SNAP categories.

Testing of PCBs in waste gases from small combustion devices (Research for HCB and PCB…, 2004), showed significantly lower contents.

The available emission factors are shown in Table 8.1.

Table 8.1 PCBs emission factors for fuel combustion, µg/t

Fuel	Technical Paper..., 1995	Lee et al, 2005	Kakareka et. al., 2004	
			Residential combustion	Domestic combustion
Fuel oil	3600			
Hard coal	3600	8800	1250	600
Peat briquette			900	600
Firewood	3500	630	600	350

Sinter production

Sintering is considered to be another source of PCBs emission. The suggested emission factor is 200 µg/t sinter (see the Chapter B331 of the Guidebook).

Electric arc furnaces

PCB emissions from electric steel smelting are stipulated by contaminated scrap use. According to (Technical Paper…, 1995; Pacyna et al., 1999), PCBs emission factors make up to 3.6 mg/t steel, the smelting process is not specified. In the European inventory this factor is taken equal for open-hearth, oxygen-converter and electric steel furnace.

According to (Harrad et al., 1993), the recommended PCBs factor for metal scrap treatment makes up to 250 mg/t scrap or 4 mg for person per year. The high values of factors may probably be explained by the use of raw materials, which probably includes PCBs containing equipment.

Electrical equipment production

The main usage of intentionally produced PCBs was production of electrical equipment. A retrospective evaluation of historical emissions of PCBs should consider emissions during electrical equipment production. The average leakage of PCBs during the process of capacitors and transformers filling in the USSR are estimated to 10 % of PCBs.

Comment [kbr2]: Do you mean produced instead of used here (and in the sentence below)?

Paint production

As for the production of electrical equipment, a retrospective evaluation of historical emissions may require consideration of emissions from open applications.
Paint production was the second large sphere of PCBs application in some countries. PCBs were used in paints and varnishes to impart weatherability, luster and adhesion.

In the former USSR Pentachlorodiphenyls (Sovol) were used for a long time as plasticizer (softener) for varnishes and enamels production. According to the AMAP data (PCB in the Russian…, 2002), six enterprises were engaged in paintwork production on the territory of the former USSR.

The production process involves the following main stages: raw materials preparation, grinding and mixing in mills; charging into mixers and vehicle preparation; pigments addition (depending on production brand), dispersion; packaging.

Leakage factors of PCBs were estimated to be 10–50 kg per tonne of PCBs use; emission factors make up 2–10 kg/t of PCBs use.

Open applications

PCBs emission factors for open application are very uncertain because of complexity of the process of PCBs evaporation from various formulations for which PCBs were used.

According to (Technical Paper…, 1995) PCBs emission factor makes up 7 % of total use of PCBs.

According to (Breivik et al., 2002 b), emission factors make up 83.6 kg/t PCBs used per year (the sum of 22 isomers). Low-molecular compounds dominate among isomers: dichlorobiphenyls (63 %) and trichlorobiphenyls (33 %).

Waste treatment and incineration

In many countries incineration of different types of wastes (especially PCB wastes or PCBs contaminated material) may be a significant source of PCB emissions.

The contribution to PCB emissions depends largely on the type of wastes and incineration technology. Incineration of PCBs and chlorine-containing wastes has the highest values of PCBs emission factors.

Utilization of PCBs and materials containing PCBs

A variety of destruction technologies are available which could provide safe and efficient destruction of PCBs. Some of these technologies are reviewed in the issue of UNEP Chemicals (Inventory of Worldwide…, 1998).

Utilization (destruction) of PCBs means breaking of molecular bonds by input of thermal or chemical energy. The main destruction processes are the following: incineration, chemical dechlorination and plasma arc system.

Incineration of PCBs and PCB-containing wastes is the most common method of PCBs destruction, especially for liquid PCBs (Inventory of Worldwide…, 1998). The main condition for effective PCBs destruction is the high temperature incineration. The minimum operating temperature for PCB liquids > 500 ppm is 1200^{o}C.

Incineration may take place in facilities, designed specifically for PCBs and other chlorinated wastes, or advantage may be taken in cement kilns, which can be licensed to accept a proportion of chlorinated wastes as fuel. The most important incineration facilities are: rotary kiln incinerators; liquid injection incinerators; static kiln incinerators; fluidized bed incinerators; cement kilns. Other types of furnaces for incineration of PCBs have also recently been used, for example blast furnaces (in Russia).

In some cases the processes of combustion are incomplete which can result in the release of PCBs or PCBs by-products. According to (Inventory of Worldwide…, 1998), destruction removal efficiency varies significant between incinerator facilities: from 99.9 to 99.99999%.

PCBs emission factors from PCBs waste incineration are given in table 8.2.

Table 8.2 PCBs emission factors of liquid PCBs waste incineration

Type of incinerator	Destruction and removal efficiency	PCBs emission factors, g/t PCBs charged	Reference
Liquid injection	99.9921–99.9995	5–79	Ackerman, 1981
Liquid injection	99.99	100	McInnes et al., 1984
Rotary kiln	99.9	100	McInnes et al., 1984
Liquid injection	99.99999	30 (0.02–29)	McInnes et al., 1984
Mobile incinerators rotary kiln	99.999	10	Ackerman, 1981
Mobile incinerators rotary kiln	99.9999	1	McInnes et al., 1984
Oil-fired boilers	99.1–99.9997	2000 (3–9000)	Locating and Estmating..., 1987
Coal-fired boilers	99.7–99.993	1000 (70–3000)	Locating and Estmating..., 1987

During the inventory of PCBs in the USA for 1990 the emission factor 1 g/t PCBs incinerated was used (1990 Emission Inventory…, 1998).

Aggregated factor of 10 g/t PCBs incinerated can be recommended.

Industrial waste incineration

PCBs emission factors are represented in table 8.3.

Table 8.3 PCBs emission factors for industrial wastes incineration, mg/t

Type of waste	Country/region	Emission factor	Reference
Solid industrial	Czech Republic	0.5–11.2 mg/t	Atmospheric Emission…, 1995
Liquid waste with PCBs	Czech Republic	8.2–30.4 mg/t	Atmospheric Emission…, 1995
Liquid waste without PCBs	Czech Republic	3.4 mg/t	Atmospheric Emission…, 1995
Tire	USA	1.89 mg/t	1990 Emission Inventory…, 1998
Chemical waste	Europe	4.6 mg/t	Technical Paper…, 1995

Municipal waste incineration

Municipal waste incineration is a potential emissions source of PCBs. The relative contribution to European emissions have previously been estimated to be 0.05 % (Berdowski et al., 1997).

From studies at waste incineration plants in Czech and Slovak Republics, PCBs emisson factors were estimated 1.0-1.9 mg/kg (Holoubek et al., 1993). According to (Atmospheric Emission…, 1995), emission factors depending on type of installations vary from 1.6 to 5.3 mg/t waste. Emission factors attributed in the USA are within the limits of 1.8-62 mg/t (average – 18 mg/t) (Locating and Estimating…, 1987).

By the (Technical Paper…, 1995), recommended emission factor is 0.82 mg/t waste. Aggregated emission factor 5 mg/t waste is recommended for the CIS countries (Kakareka, Kukharchyk, 2002).

PCBs emission factors for municipal wastes incineration are presented in the table 8.4.

Table 8.4. PCBs emission factors for municipal wastes incineration

Country/region	Emission factor	Reference
Czech Republic	1.6-5.3 mg/t	Atmospheric Emission…, 1995
Europe	0.82 mg/t	Technical Paper…, 1995
USA	2.7 mg/t	1990 Emission Inventory…, 1998
USA	1.8-62 mg/t	Locating and Estimating…, 1987
Japan	10.4–18.5 mg/t	Sakai et al., 1999
CIS	5 mg/t	Kakareka, Kukharchyk, 2002

Medical waste incineration

Testing at 4 waste combustion installations in the USA gave the following emission factors for PCBs – 8.55–21.8 µg/t (The Inventory of Sources…, 1998); according to (1990 Emission Inventory…, 1998), incineration of medical and others biological wastes leads to emission of 23.2 mg/t PCBs per tone of waste (table 8.5). Close value (20 mg/t) is shown in (Atmospheric Emission Inventory…, 1999) with reference to EPA (1998).

Table 8.5. – PCBs emission factors for medical wastes incineration

Type of waste	Country/region	Emission factor	Reference
Medical and biological waste	USA	23.2 mg/t	1990 Emission Inventory…, 1998
	USA	8.55-21.8 µg/t	The Inventory of Sources…, 1998
Medical waste	Czech Republic	2 µg/t	Middle European…, 1999

Sewage sludge incineration

According to (Locating and Estimation…, 1987), emission factor for sewage sludge with unknown contamination of PCBs makes up to 4.5 mg/t sludge. In the (Source Characterization…, 2000) an emission factor of 4.9 µg/t is suggested.

PCBs evaporation from reservoirs

Contaminated soils and bottom sediments, landfills containing industrial and municipal wastes are potentially important sources of PCB emissions. This is an important issue in developing countries in particular, and in countries with economics in transition. In these countries problems of PCBs waste management are typical. Furthermore, there are few facilities for destroying PCBs in an environmentally safe manner. The amount of PCBs-containing equipment out of operation (including damaged) may increase as well as PCBs leakage and environmental pollution.

For estimation of emissions from these sources modeling should be made with data on PCBs content in substrate (soil, sediments, etc), area of contamination, physical and chemical parameters of substrates and others. By now in most cases it is impossible to collect enough data for such estimated due to lack of studies and complexity of PCBs emission process.

Virtually all of the PCBs are evaporated from sand, while less than 10 % was evaporated from topsoil rich in organic matter. The rate of volatilization increased with temperature and wind speed.

In the USA PCBs emission inventory factor was taken to be 4.286 kg/t wastes containing PCBs (Locating and Estimating…, 1987). For landfills of municipal wastes this factor depends on dump methane emissions and PCB emissions. The recommended factor according to (Technical Paper…, 1995) makes up to 0.3 µg/m^3 CH_4. According to (Locating and Estimating…, 1987) this value equals to 0.19 µg/m^3 CH_4.

The level of PCBs emission from landfills highly depends on the type of PCB wastes and to a lesser extent – on the content of PCBs in wastes. Thus, the investigation of Persson et. al. (2005), showed emission flux of PCBs from landfill which contains 10-18 tonnes PCBs in polysulphide sealant is about 1 g Σ PCB/yr only.

Municipal waste open burning

Open burning of waste is widely used in many countries (Introduction to Area …, 1999; The European Dioxin…, 2000). This activity is illegal and is connected, as a rule, with ineffective wastes collection and removal and their further accumulation (first of all, packaging material). A list of wastes burnt in bonfires is rather large: paper, paperboard, packaging material, polyethylene film, contaminated wood, rags, automobile and tractor tires, plastic bottles, waste food, etc. Often street sweep which contains a great share of domestic wastes are burnt. Spontaneous fires are unavoidable on sanitary landfills of solid wastes and also in places of their unauthorized accumulation.

The variety of substrates and combustion conditions is a source of a large number of POPs and PCBs formation.

The emission factor suggested by EPA (1997) makes up to 2.86 g/t combusted waste.

The set of default emission factors which may be used if no more data available on emission of PCBs is given in the table 8.6.

Table 8.6 Default emission factors of PCBs

Source category	SNAP	Emission factor	Unit
Stationary fuel combustion	**01+02+03**		
Non-industial combustion plants	**02**		
Fuel oil		3600	µg/t
Hard coal		4500	µg/t
Peat briquette		900	µg/t
Firewood		600	µg/t
Production processes	**03&04**		
Sinter plants	030301	200	µg/t
Electric arc furnaces	040207	3.6	mg/t
PCBs-containing paint production	**060307**	5	kg/t
PCBs-containing paint use (open application)	**0601**	80	kg/t
Waste treatment and disposal	**09**		
PCBs incineration		10	g/t
Incineration of domestic or municipal wastes	090201	5	mg/t
Incineration of industrial wastes	090202	5	mg/t
Incineration of hospital wastes	090207	20	mg/t
Incineration of sludge from waste water treatment	090205	5	mg/t
Other sources and sinks			
Electrical equipment	N/A		See chapter Electrical Equipment

9 SPECIES PROFILES

Commercial PCBs formulations are mixtures of PCBs with different levels of chlorination and positions of chlorines on the molecules. According to (Breivik et al., 2002a and 2002b), more than 70% of the global production of PCBs is represented by tri-, tetra-and pentachlorinated biphenyls. Although the isomer profiles are fairly well established for most technical formulations of PCBs that were produced in the past, the actual emission profile is expected to show a high variability. No default species profile are therefore suggested for the individual emission factors presented herein.

10 UNCERTAINTY ESTIMATES

Generally PCBs emission calculations have great uncertainty due to complexity of PCB emissions, their low levels, and the lack of empirical data from relevant studies.

The uncertainty of PCBs emission calculation consists of uncertainties of emission factors and uncertainties of statistical (production / activity) data. First type of uncertainty can be estimated statistically on the basis of experimental data on PCBs concentration variability in emission; second type depends on accuracy of statistical data and varies from country to country.

On the whole, the precision and accuracy of emission calculation depends mainly on the quality of emission factors. If aggregated or default emission factors are used, their uncertainties are expected to be high. But for PCBs lack of statistical data for some source categories also results in high level of uncertainty.

11 WEAKEST ASPECTS IN CURRENT METHODOLOGY

There are a lot of weak points in PCBs emission estimates due to a complexity of factors affecting these pollutants emission. Inventory of PCBs produced (imported), in use, at storage and disposal should be considered the priority elements of PCBs emission inventory improvement.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

13 TEMPORAL DISAGGREGATION CRITERIA

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCESSES

Simplest verification of emissions can be done by comparing the results of emission inventory of PCBs in similar countries.

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