

**SNAP CODE:** N/A

**SOURCE ACTIVITY TITLE:** Electrical Equipment Containing PCBs

**NOSE CODE:** 112.09.13

## 1 ACTIVITIES INCLUDED

This chapter covers emissions to atmosphere from electrical equipment containing PCBs. It covers emissions which result from existing electrical equipment containing PCBs, through leaks or spills, and from the recycling of this equipment by fragmentising / shredding.

This chapter does not cover emissions from landfill, from the burning of electrical equipment containing PCBs through accidental or deliberate fires (SNAP 09), from the processes of utilisation of electrical equipment, and emissions from open applications of PCBs.

## 2 CONTRIBUTION TO TOTAL EMISSIONS

The major use of PCBs, and so the main source of secondary environmental pollution by PCBs, is electrical equipment. In the UK, for example, it is estimated that over 90% of PCB emissions arise from leaks from transformers and capacitors and from fragmentising operations (APARG, 1995). Recent estimates of the European emissions in 1990 indicate that as much as 94% of PCB emissions come from this source (Berdowski et al., 1997). Electrical equipment containing PCBs is unlikely to be a significant source of any pollutant other than PCBs.

**Table 2.1 Contribution to total emissions of the CORINAIR90 inventory**

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO <sub>2</sub>	NO <sub>x</sub>	NMVOC	CH <sub>4</sub>	CO	CO <sub>2</sub>	N <sub>2</sub> O	NH <sub>3</sub>
Electrical equipment containing PCBs		-	-	-	-	-	-	-	-

- = no emissions are reported

**Table 2.2 Contribution to total POP and heavy metal emissions of the OSPARCOM HELCOM-UNECE emission inventory (up to 39 countries)**

Source-activity	SNAP-code	Contribution to total emissions (including emissions from nature) [%]									
		As	Cr	Cu	Pb	Cd	Hg	PCBs	PCDD/Fs	HCB	PCP
Electrical equipment		0	0	0	0	0	0	94	0	0	0

- = no emissions are reported

### 3 GENERAL

#### 3.1 Description

PCBs are synthetic organic compounds, which mix well with organic solvents and plastics, etc. They are stable to strong acids and alkalis. This high chemical stability, together with their electrical stability (particularly at variable voltage), as well as their resistance to degradation at high temperatures, have in the past resulted in a range of industrial applications. PCBs were widely used as dielectric fluids for a long period (approx. from 1929 to 1988), mainly in industrial transformers and capacitors.

The main difficulty in compiling an inventory of PCB emissions is the tracking and identification of PCB-containing equipment, since there are no relevant readily available statistics.

#### 3.2 Definitions

Capacitor - a device for accumulating and holding a charge of electricity. Some were made with PCBs as the dielectric fluid.

Dielectric fluid - insulating material used in electrical equipment, separating the conduction surfaces (sometimes containing PCBs).

Fragmentising operations - the breaking up of household appliances (e.g. cookers, refrigerators) for recycling.

PCBs - polychlorinated biphenyls. A subset of the synthetic organic chemicals known as chlorinated hydrocarbons; this includes 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 number of chlorine atoms within the range of 1-10. A total of 209 individual isomers exist; these range from liquids to high-melting crystalline solids.

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

#### 3.3 Activities

##### 3.3.1 Electrical equipment and PCB use

The main use of PCBs has been as dielectric insulating materials in electrical equipment such as capacitors and transformers (see Table 3.1). Most countries have not manufactured PCBs for many years, but many of the old appliances still exist; the useful life of such appliances is 20-30 years.

**Table 3.1 Use of PCBs in USA, Germany, Japan and Russia**

Country	% of total PCBs used as dielectric fluids	Reference
USA	until 1971, 61%; after 1971, 100%	USEPA, 1987
Germany	55.5%	Dobson and van Esch, 1993
Japan	66%	Neumeier, 1998
Russia	75%	Kakareka et al., 2000

The majority (70%) of capacitors are used as power capacitors; high frequency capacitors have the next highest usage (Gulevich, 1981, data for the former USSR). Power capacitors are used in high and low voltage transmission lines or in high frequency transmission units for a variety of purposes, such as:

- to increase the capacity factor of industrial electrical units;
- to increase the capacity factor of induction electrical and thermal units;
- to compensate for reactive resistance of long-distance power transmissions;
- to take off power from high voltage transmission lines;
- to filter traction substation;
- to generate impulse current and voltage;
- to start capacitor electric motors;
- in mine electric locomotives;
- in ultrasonic units.

They can be used both as separate units and in the form of complex capacitor units or batteries.

**Power capacitors** produced in different countries have similar size parameters. Large high voltage capacitors typically weigh 54 kg, of which 11 kg are PCBs (USEPA, 1987); power factor correction capacitors produced in the USSR have 2 typical sizes, weighing 28-35 kg and 54-60 kg, of which 10 and 19 kg are PCBs respectively (Kakareka, 2000).

**Small capacitors** include motor start capacitors and ballast capacitors. Motor start capacitors are used with single phase motors to provide starting torque; these capacitors can be found also in household electrical appliances including refrigerators, cookers, washing machines, air conditioners, dishwashers, etc (UNEP, 1999). Many such appliances are still in use but it is difficult to establish what proportion of these goods have PCB-containing components. Ballast capacitors are found within fluorescent, mercury, and sodium lighting fixtures, and neon lights; they typically weigh 1.6 kg, of which 0.05 kg are PCBs (USEPA, 1987).

**Transformers** are used for electric power transformation in power transmission lines and in power energy receipt and use units. The transformer is a very important component in different types of electrical circuits, from small-signal electronic circuits to high-voltage power transmission systems. The physical size and shape of transformers, and therefore the volume of PCBs in them, vary greatly. Transformers can range in size from not much bigger than a pea up to the size of a small house (UNEP 1999); the volume of PCBs typically ranges from 0.2 to 4.1 tonnes (Kakareka, 2000).

### 3.3.2 PCBs as dielectric fluid

Commercial products known generically as PCBs are mixtures of individual isomers in which the chlorine content is between 21 and 68%. Registered trade names for some commercial brands of PCBs are: Aroclor, Chlorinol, Askarel, Dykanol, Pyranol (USA), Pyralene (France), Clophen (Germany), Kannechlor (Japan), Delor (Czechoslovakia), Sovol, Trichlorobiphenyls, Sovtol (USSR). Arochlor is the best known of the PCB formulation and has served as a standard. Example characteristics are shown in Table 3.2.

**Table 3.2 Chlorinated liquid dielectric characteristics (Kakareka, 2000)**

Name	Composition	Density at 20°C, kg/m <sup>3</sup>	Chlorine content, %
<b>For capacitors</b>			
Sovol	Pentachlorobiphenyl	1.55	54.6
TCB	Trichlorobiphenyl	1.4	42
Aroclor 1232	Dichlorobiphenyl	1.27-1.28	32
Aroclor 1242	Trichlorobiphenyl	1.38-1.39	42
Aroclor 1248	Tetrachlorobiphenyl	1.405-1.415	48
Aroclor 1254	Pentachlorobiphenyl	1.495-1.505	54
Clophen A-30	Trichlorobiphenyl	1.35	42
Pyralene 1460	Polychlorobiphenyls+Polychlorobenzenes	1.41	
Pyralene 1499	Trichlorobiphenyl	1.38	42
Pyralene 2000	Dichlorobiphenyl	1.29	32
Pyralene 3010	Trichlorobiphenyl	1.38	42
Pyralene 5000	Pentachlorobiphenyl	1.55	54
<b>For transformers</b>			
Askarel	Polychlorobiphenyls (60-70%) + Chlorobenzene (30-40%)		
Sovtol-10	Pentachlorobiphenyl (90%) + Trichlorobenzene (10%)	1.52-1.54	
Hexol	Pentachlorobiphenyl (20%) + Hexachlorobutadiene (80%)	1.64	

### 3.3.3 Leaks from transformers and capacitors

The majority of emissions of PCBs arise from leaks from electrical transformers and capacitors which contain PCBs and which are in a poor condition and/or are poorly maintained.

It is likely that the oil of some transformers that were not originally deliberately filled with PCBs has become contaminated with PCBs. However, it is estimated that over 90% of these transformers are contaminated to levels less than 50 ppm (APARG 1995). The source of this contamination is likely to be the lack of segregation in the past of oil and PCB filling lines at manufacturers' works, and the subsequent use of recycled oil.

### 3.3.4 Fragmentising operations

Some small capacitors containing PCBs will be landfilled with household waste, but most will be in appliances that will be partly recycled by fragmentising. This is the process by which domestic electrical appliances are shredded and the fragments separated into the following 3 fractions:

- ferrous metal, which is recycled to steel producers;

- a non-ferrous metal enriched 'heavy' fraction, which is mainly disposed to landfill following processing to remove the non-ferrous metals;
- a 'light' or 'dirt' fraction that consists largely of non-metallic waste materials (e.g. wood, glass, plastic etc), which is mainly disposed to landfill.

There is the potential for PCB release both from fragmentiser wastes disposed to landfill and from the fragmentiser process itself, as well as during metal processes when recycled ferrous metal is used. The release of PCBs to atmosphere greatly depends on the process temperatures.

### **3.3.5 Disposal of electrical equipment containing PCBs**

Large quantities of PCBs have been disposed to landfill in the past, mainly in the form of electrical components or fragmentiser residues, but discarded electrical equipment known to contain PCBs is now often disposed of by chemical waste incinerators. However, emissions from disposal of electrical equipment are not covered by this chapter.

### **3.4 Emissions**

The major source of PCBs arises from leaks of dielectric fluid containing PCBs from large electrical transformers and capacitors which are in poor condition. PCB emissions from transformers and capacitors during normal operation are negligible (section 3.3.3).

In addition, fragmentising operations are also likely to be significant sources of PCBs where electrical appliances containing PCBs are involved (section 3.3.4).

### **3.5 Controls**

Not all PCB-filled transformers are identifiable, although many of the ones that are known are owned by organisations that operate to rigorous safety standards. In such cases the environmental impact of leaks from the transformers has therefore been minimised. These transformers can be landfilled after being drained and flushed, and the PCBs are accessible for controlled disposal, usually by incineration.

## **4 SIMPLER METHODOLOGY**

There are limited data available on emissions of PCBs from electrical equipment and therefore the simple methodology is based on emission factors which have been developed by calculation, using population as the activity. The emissions can be estimated using the equations below. Default emission factors are given in Section 8.

### **Transformers and Capacitors**

Atmospheric emission of PCBs from transformers/capacitors  
= (per capita emission factor) x (population)

## Fragmentising Operations

Atmospheric emission of PCBs from fragmentising operations  
= (per capita emission factor) x (population)

For the emission of PCBs from fragmentising operations, the emission can also be estimated using an emission factor based on the quantity of ferrous scrap recycled, using the equation:

Atmospheric emission of PCBs from fragmentising operations  
= (emission factor per unit mass of ferrous metal recycled) x (mass of ferrous metal recycled)

## 5 DETAILED METHODOLOGY

The detailed methodology involves a review of the estimated number of transformers and capacitors in a country and an analysis of the proportion of these which contain PCBs and the proportion which have the potential to leak. This analysis would therefore require a more detailed audit of electrical equipment within a country.

Similarly, for fragmentising operations, the detailed methodology involves an analysis of the types of ferrous scrap recycled, and requires more detailed knowledge of the quantity of PCBs within the different types of ferrous scrap.

The first stage in the inventory of electrical equipment with PCBs requires the identification of power capacitors and power transformers, ie those devices where most of the PCBs have been used. This group alone can consist of thousands of appliances distributed over hundreds of users, so their full inventory is a very complicated task. As the first approximation a selective inventory of main users can be proposed.

This inventory should detail separately transformers and capacitors, with an indication of their type, dielectric type, equipment number, year of manufacture, producer. Electrical equipment that was in operation, in reserve or damaged must also be taken into account. It is not always possible to determine the capacitor type and the year of its manufacture; there are problems of dielectric type determination (often it is defined under a general name 'synthetic'). It is difficult to track equipment as in many cases capacitors have no registration certificates, as there are no regulations for PCB-containing equipment operation; also some equipment may have been stored at dumps or used for other purposes.

The second stage of PCB inventory includes calculation of the volume of dielectric fluids. The amount of dielectrics in large capacitors varies depending on its type from 2.7 kg to 22-24 kg; most of the widely used power capacitors contain 14 kg of PCBs. The volume of PCBs in transformers varies depending on its type from 0.2 t to 4.1 t (Kakareka, 2000).

Default emission factors are given in Section 8.

## **6 RELEVANT ACTIVITY STATISTICS**

### **6.1 Simple methodology**

The simple methodology for estimating PCB emissions from leaks from transformers and capacitors requires knowledge of the population in a country. This information will be available from national statistics offices.

The simple methodology for estimating PCB emissions from fragmentising operations requires knowledge of the population or the quantity of ferrous scrap recycled in a country.

### **6.2 Detailed methodology**

The detailed methodology for estimating PCB emissions from leaks from transformers and capacitors requires detailed knowledge of the quantities of transformers and capacitors which contain PCBs and their state of maintenance. This information might be available from national Electricity Associations.

The detailed methodology for estimating PCB emissions from fragmentising operations requires knowledge of the quantities and types of ferrous scrap recycled and the quantity of PCBs in the types of ferrous scrap.

## **7 POINT SOURCE CRITERIA**

Although leaks from electrical equipment sites might be significant, limited information is likely to be available on the location and scale of leaks. Therefore electrical equipment should be treated as area sources unless reliable site specific data are available.

## **8 EMISSION FACTORS, QUALITY CODES AND REFERENCES**

Concerning emission factors presented in Table 8.1, Berdowski et al. (1997) have calculated emissions of PCBs due to leaks from transformers and capacitors for each of the European countries in 1990. The range of the per capita emission factors is large; almost two orders of magnitude. This indicates a difficulty in choosing a proper emission factor and the high uncertainty of emission estimates on the basis of these emission factors.

Table 8.3 gives default emission factors for calculating emissions to air from the amount of leakage of PCBs. The process of evaporation is very complex and has not been well studied, although it is known that rate of evaporation decreases with increase of level chlorination of PCB; therefore Trichlorobiphenyl, which is used in, and leaks from, capacitors, will evaporate more rapidly than Pentachlorobiphenyl (Sovtol-10 or other brand) from transformers.

**Table 8.1 Emission factors for leaks from transformers and capacitors**

Compound	Equipment / process	Abatement type	Abatement efficiency	Fuel type	Emission factor	Data Quality	Country or region	Reference
Total PCBs	Leaks from transformers	None	N/A	N/A	<b>0.006 - 0.5 g/capita/year</b> <sup>1</sup>	<b>E</b>	Europe	Berdowski et al. (1997)

<sup>1</sup> Recommended emission factor 0.13 g/capita/year

**Table 8.2 Emission factors for fragmentising operations (recycling of ferrous scrap)**

Compound	Equipment / process	Abatement type	Abatement efficiency	Fuel type	Emission factor	Data Quality	Country or region	Reference
Total PCBs	Fragmentiser operations (recycling of ferrous scrap)	None	N/A	N/A	<b>0.004 g/capita/year</b>	<b>E</b>	UK	Harrad et al. (1993)
Total PCBs	Fragmentiser operations (recycling of ferrous scrap)	None	N/A	N/A	<b>0.25 g/t of ferrous scrap recycled</b>	<b>E</b>	UK	Harrad et al. (1993)

**Table 8.3 Leaks (releases) and emission factors of PCBs from electrical equipment, kg/t**

<b>Equipment</b>	<b>Leaks (releases)</b>	<b>Emission to air</b>	<b>Country or region</b>	<b>Reference</b>
Transformers	0.06	-	Europe	TNO, 1995
	0.3	-	North America	USEPA, 1997
	0.3	0.06	CIS countries	Belarusian report to EMEP, 2000
Capacitors	1.6	-	Europe	TNO, 1995
	4.2	-	North America	USEPA, 1997
	2.0	0.8	CIS countries	Belarusian report to EMEP, 2000

## **9 SPECIES PROFILES**

No information is available on the PCB species profiles from electrical equipment.

## **10 UNCERTAINTY ESTIMATES**

The majority of PCB emissions arise from electrical transformers and capacitors in poor condition, and by the nature of this source emissions are difficult to estimate. The use of per capita emission factors is uncertain because the emission factors are likely to vary significantly between countries. For example the quantity of PCBs remaining in electrical equipment will vary as well as the standard of maintenance and quality of safety procedures to prevent leaks.

The emission factors in Section 8 are based on calculations rather than measurement. The emission factors therefore have a data quality of E.

A key uncertainty is that, although the approximate quantity of PCBs produced in the past is known, the exact quantity of PCBs still in existence is unknown. Other uncertainties include the possibility of double counting in the total PCB inventory as PCB emissions from landfill are likely to include emissions that arise from electrical equipment disposed to landfill. However, this uncertainty is less important compared with those described above.

## **11 WEAKEST ASPECTS / PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY**

The weakest aspect of the methodology is the emission factors, which are very uncertain for the reasons described in Section 10. The emission factors can be improved by improving the knowledge of the quantity of PCBs in existing electrical equipment and the rate of leakage.

## **12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES**

PCB emissions from electrical equipment can be assumed to be spatially disaggregated according to population unless reliable data are available on leaks from specific sites.

## **13 TEMPORAL DISAGGREGATION CRITERIA**

Until better information becomes available, emissions may be considered to occur evenly through out the diurnal and annual cycles. However, as electrical equipment containing PCBs continues to be replaced, emissions will in reality decrease with time.

## **14 ADDITIONAL COMMENTS**

There are no additional comments.

## 15 SUPPLEMENTARY DOCUMENTS

Supplementary documents are not required.

## 16 VERIFICATION PROCEDURES

Verification procedures are in line with the priority requirements for improvement described in section 11, i.e. improved knowledge of the quantity of PCBs in existing electrical equipment and the rate of leakage is required to verify the emission factors. In addition, the research into the variation in leakage between countries could verify whether the use of per capita emission factors is reliable.

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## 19 RELEASE VERSION, DATE AND SOURCE

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**SNAP CODE:** N/A

**SOURCE ACTIVITY TITLE:** **Products containing mercury**

**NOSE CODES:** **112.09.14**  
**112.09.15**

## 1 ACTIVITIES INCLUDED

This chapter considers mercury emissions from the manufacturing, use and disposal of products containing mercury.

The main products containing mercury are divided into four categories:

- batteries;
- measuring and control equipment;
- electrical equipment;
- lighting.

The ‘destination’ of these products after their use has been divided into five different pathways including recycling, recovery and different ways of disposal. Emissions of mercury from products which have been disposed in landfill are included in this chapter.

Emissions from incineration and secondary steel/copper production are not covered in this chapter since they are included in chapters in SNAP Group 3 and 9 respectively.

## 2 CONTRIBUTION TO TOTAL EMISSIONS

Mercury emissions from products containing mercury have been estimated for Western and Eastern Europe by WS Atkins (1997), and are given in Table 2.1, below:

**Table 2.1 Estimated annual mercury emissions in Western and Eastern Europe**

Source	Western Europe (1995) (tonnes)	Eastern Europe (1995) (tonnes)
Batteries	0.09	0.015
Measuring and Control Equipment	1.81	0.500
Electrical Equipment	0.77	0.125
Lighting	0.21	0.121
<b>Total</b>	<b>2.88</b>	<b>0.761</b>

(WS Atkins, 1997)

**Table 2.2 Contribution to total mercury emissions of the OSPARCOM-HELCOM-UNECE emission inventory (up to 39 countries)**

Source-activity	SNAP-code	Contribution to total mercury emissions [%]
Mercury thermometers and vapour lamps		0.3 %

The contribution to total mercury emissions from products containing mercury varies significantly from country to country. It has been estimated (AEAT Environment 1998) that the total Hg emission for the UK was 20.5 tonnes in 1995. The contribution to total mercury emissions for the UK in 1995 was estimated to be 2% (AEAT Environment 1998).

### 3 GENERAL

#### 3.1 Description / Definitions

The sources of emissions representing this sector have been divided into four groups:

1. Batteries, including button cells (used in hearing aids, calculators, photographic equipment etc.);
2. Measuring and control equipment including laboratory and hospital equipment (including thermometers) and devices such as barometers;
3. Electrical equipment;
4. Lighting.

In the third group, mercury is used in a range of electrical equipment, including Level, Multipoled, Thermo and mechanical switches, which are used for railway signals, telecommunications, computer communications and data transmission, portable telephones, burglar alarms and hearing aids.

For lighting, mercury is used in discharge lamps including fluorescent tubes, high pressure mercury vapour, metal halide and high and low pressure sodium lamps.

Other products containing mercury are paints, pharmaceuticals, other medical/health products and dental amalgams, but the emissions from those products are unlikely to be significant and have not been included in the calculations (Maxson 1991).

#### 3.2 Techniques

Not applicable.

### 3.3 Emissions

Mercury emissions from products containing mercury can derive from the manufacturing process, the different ‘final destination’ sources after disposal and fugitive emissions from the different stages of the disposal procedure.

Disposal has been divided into 6 different pathways (WS Atkins 1997):

- Recollection/Recycling;
- Incineration/burning of waste including products containing mercury;
- Steel/copper scrap;
- Disposal via landfill;
- Release by breaking;
- Accumulation/recovery.

From the distribution factors tabulated below (Tables 3.1 and 3.2), it is evident that the biggest proportion of the mercury content of products ends up in landfill. In Eastern Europe, a big proportion of the disposed products is openly burnt rather than incinerated, or dumped rather than disposed in a covered landfill.

**Table 3.1 Distribution factors for Western Europe**

Pathway	Batteries	Measuring and control equipment	Electrical equipment	Lighting
Recollection / recycling	0.3	0.1	0.1	0.1
Incineration	0.14	0.1	0.08	0.09
Steel / copper scrap	0	0	0.1	0
Landfill	0.55	0.4	0.32	0.36
Release by breaking	0.01	0.05	0	0.05
Accumulation / recovery	0	0.35	0.4	0.4

(WS Atkins 1997)

**Table 3.2 Distribution factors for Eastern Europe**

Pathway	Batteries	Measuring and control equipment	Electrical equipment	Lighting
Recollection / recycling	0	0	0	0
Open burning / incineration	0.495	0.3	0.25	0.275
Steel / copper scrap	0	0	0.1	0
Dumped / Landfill	0.495	0.3	0.25	0.275
Release by breaking	0.01	0.05	0	0.05
Accumulation / recovery	0	0.35	0.4	0.4

(WS Atkins 1997)

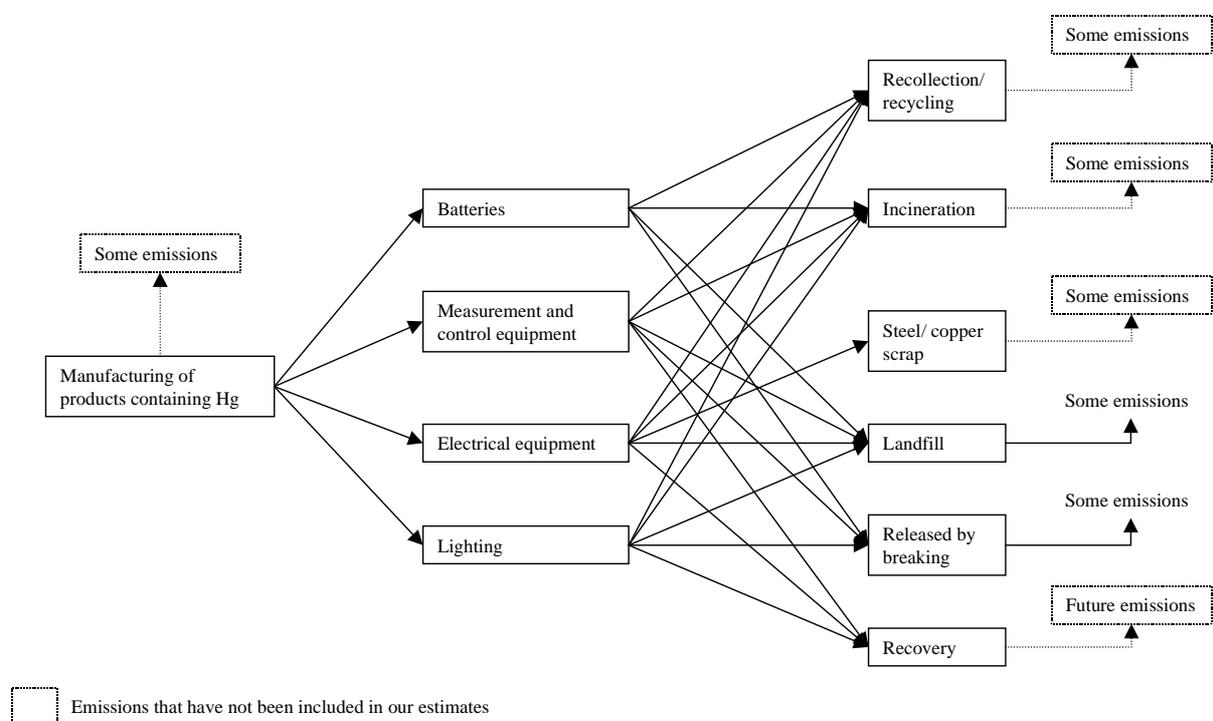
Regarding the steel/copper scrap pathway, the electrical equipment that ends up in a steel/copper scrap are fragmented and the steel/copper parts recycled. Mercury may also be emitted through the fragmentation process.

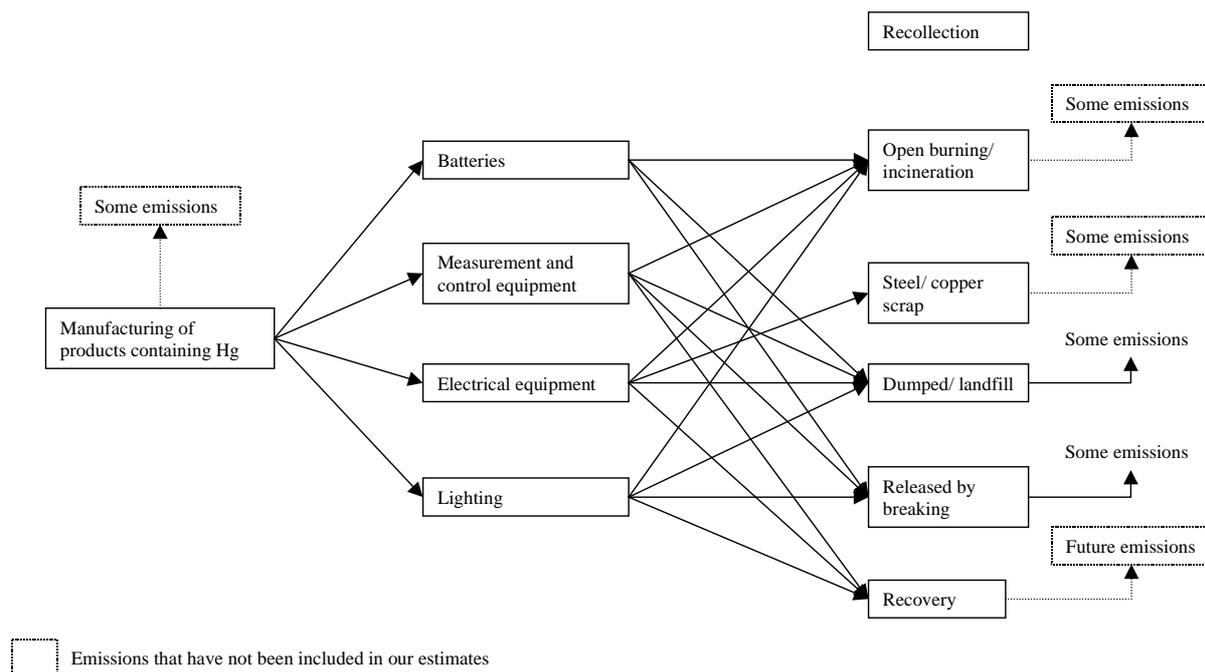
Additionally, mercury is emitted via the incineration of wastes that include products containing mercury. Emissions from recycling of steel/copper scrap and from incineration are covered in other chapters.

Studies (Maxson 1991 and WS Atkins 1997) have considered the recovery of mercury from products as a separate destination before disposal. It can be assumed that the currently recovered mercury will be disposed and potentially emitted through the above mentioned pathways in the future. This additional emission has not been included in the calculation of mercury emission factors in this chapter.

In summary, the annual mercury emissions from products have been calculated by considering emissions from landfills and releases from the breaking of products containing mercury. Mercury emissions from the manufacturing process of products containing mercury, the recycling process and the fragmentation of the electrical components that end up in a metal scrap are considered to be relatively low and are not included in the calculation of mercury emissions. Future emissions from currently recovered mercury has not been considered either.

**Figure 3.1 Pathways of emission sources in Western Europe**



**Figure 3.2 Pathways of emission sources in Eastern Europe**

The emission factors differ depending on the product and destination. In general, the emission factors are higher in Eastern Europe, mostly because of less modern technology (WS Atkins 1997).

Considering the fact that almost 50% of the products containing mercury end up in the landfill in Western Europe, landfills/dumping can be considered as the major source of mercury emissions for the whole of UNECE.

### 3.4 Controls

Options to reduce mercury emissions from this sector include:

- Banning/phasing out of the production and sale of products containing or needing metallic mercury for their functioning;
- Limitation of the amount of mercury in products.

These will depend on the availability of substitutes not containing mercury and the actual need to use products containing mercury in the future.

### 3.4.1 Batteries

Since 1990, mercury consumption in primary batteries has declined significantly in the EU due to the introduction of the Directive 91/157/EEC on batteries and accumulators containing certain dangerous substances. The Directive came into force in 1994 (NSCA 1998).

The Directive covers, amongst the other types of batteries, the commonly used alkaline-manganese energy cell, the zinc-carbon battery, the zinc-air button cell as well as the silver oxide button cell and the mercuric oxide battery (two small battery types which also contain mercury). Most of mercury-oxide batteries can be substituted by zinc-air (whose power characteristics are being improved rapidly), silver-oxide and lithium batteries. Zinc-carbon and a significant percentage of alkaline-manganese batteries will soon be mercury-free (Maxson 1991). Silver Oxide batteries, are being recycled by jewellers and watch repairers and mercuric oxide batteries (used in hearing aids) are declining in number (Haigh 1995).

Consequently, the biggest part of current mercury emissions from batteries in the EU originates from special purpose mercury button cells.

### 3.4.2 Measuring and control equipment

Until now there is no legislation regarding the consumption of mercury in measuring and control equipment. Studies have shown that mercury thermometers are likely to be replaced by digital electronic ones or heat sensitive instruments based on liquid crystals (Maxson 1991).

### 3.4.3 Electrical Equipment and Lighting

There is no legislation regarding electrical equipment and lighting.

Two Directives establishing the ecological criteria for the award for the Community eco-label to single-ended (95/533) and double ended (96/337) light bulbs can probably be used as an incentive towards the reduction of the use of mercury in these products.

Due to the likely forthcoming legislation, some industry is trying to find mercury-free substitutes, in order to reduce the use of mercury in different items. For example in the electrical equipment category, mercury usage in reed switches is being phased out, but mercury is still used in tilt switches in the automotive industry.

Consumption estimates for fluorescent tubes in the mid-1990s, based on 1989 figures, have found that the levels had remained almost unchanged. In Western Europe, mercury consumption in individual lamps is declining, but use of fluorescent lamps is increasing slightly. It has been estimated, that since 1990, mercury consumption in lamps has declined by about a third (WS Atkins 1997). Additionally, discharge lamps are more energy efficient than incandescent lamps and their longer life contributes to lower mercury emissions in electricity generation (WS Atkins 1997).

#### 4 SIMPLER METHODOLOGY

The simpler methodology involves the combination of emission factors according to different category from the four product types mentioned earlier (e.g. Hg emissions per million population) with activity statistics (e.g. population of each country for a certain year). Equation (1) gives an example of the simple methodology:

$$\text{Total Emission} = \sum_{\text{different products}} [\text{Hg emission per capita}] \times [\text{Population}] \quad (1)$$

Emissions from the manufacturing process, the recycling and the fragmentation stages are not included.

#### 5 DETAILED METHODOLOGY

The detailed methodology for Hg emissions may initially involve a mercury audit to find out the amount of the Hg content in different products and the amount of products sold per year. Collection of data can take place by sector after the manufacturing plants have been located. Estimates for each sector would be combined to give a more accurate estimate of the total emission.

Audits on the destinations of the different products have to be carried out for better estimates on the distribution factors.

Emissions from the manufacturing process should be added. Also, emissions from the recycling process of products that have been recollected, as well as an estimate of emissions from the fragmentation of products that end to the metal scrap, can be included.

Equation (2) is an example of how to calculate Hg emissions for each category:

$$\begin{aligned} [\text{Hg emission}]_{\text{product}} = & \{ [\text{Mass of Hg used in each item}] \times [\text{Items consumed per year}] \} \times \\ & \sum_{\text{Distribution f(pathway)}} \{ \frac{[\text{Distribution factor}]_{\text{Distribution f(pathway)}}}{[\text{Emission factor}]_{\text{Distribution f(pathway)}}} \} \quad + \\ & \frac{[\text{Emissions from manufacturing process}]_{\text{product}}}{[\text{Number of manufacturing plants}]_{\text{product}}} \quad + \\ & [\text{Emissions from recycling process after recollection}]_{\text{product}} \quad + \\ & [\text{Emissions from fragmentation of metal scrap}] \quad (2) \end{aligned}$$

However, it is unlikely that information is available at present to enable the detailed methodology to be used in order to improve emissions estimated by the simple method.

## **6 RELEVANT ACTIVITY STATISTICS**

### **6.1 Simpler methodology**

The simpler methodology requires the following activity statistics:

- population of the country

### **6.2 Detailed methodology**

The detailed methodology requires the following activity statistics for each plant:

- mass of mercury contained in products containing mercury per year;
- amount of items consumed per year;
- number of plants producing products containing mercury;
- details about the extent of recollection/recycling;
- details about the fragmentation process.

For some countries, national statistics are not easy to obtain and it may be necessary to directly contact manufacturing plants and trade organisations.

## **7 POINT SOURCE CRITERIA**

The biggest part of the emissions for the whole of Europe derives from the landfills or because products have been dumped. Therefore, landfills should be considered as a point source where site specific data are available. Otherwise they should be considered as area sources.

As the contribution of the mercury emissions from products containing mercury to the overall mercury emissions represents only a small percentage, other emission pathways covered by this chapter can be considered as an area source.

## 8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

### 8.1 Simpler Methodology

**Table 8.1 Emission Factors for Hg from products containing Hg**

Compound	Product	Emission factor (tonnes per million population)		Data Quality	Reference
		Western Europe	Eastern Europe		
Hg	Batteries	0.0002	0.00004	E	WS Atkins 1997
Hg	Measurement and control equipment	0.0044	0.0013	E	WS Atkins 1997
Hg	Electrical equipment	0.0019	0.0003	E	WS Atkins 1997
Hg	Lighting	0.0005	0.0003	E	WS Atkins 1997

### 8.2 Detailed Methodology

Emission factors should be derived through any measurement data. However, these are unlikely to be available in sufficient detail to improve emission estimated by the simple method.

## 9 SPECIES PROFILES

Species profiles are not applicable.

## 10 UNCERTAINTY ESTIMATES

There is an uncertainty in estimating mercury emissions from mercury containing products:

- during the manufacturing process;
- during the recycling process, after products containing mercury have been recollected;
- during the fragmentation stage of the products containing mercury that have ended in a steel/copper scrap.

There is also much uncertainty in the distribution factors, the emission factors and the activity statistics.

## **11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY**

The weakest aspect of the methodology is the accuracy of the emission factors and the lack of field-based emission data.

The recommended emission factors should be improved through measurement. However since there is a difficulty in making these measurements, activity data should be investigated first. If the investigation shows that activities are decreasing, then it will be less necessary for measurements to be carried out.

The EPBA (1992) report suggests that emissions via disposal of dental amalgams might be as significant as some of the main four product categories, and this needs to be reviewed.

If the chapter on landfills (90400) is updated to include mercury emissions, then the potential for double counting should be addressed.

## **12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES**

Mercury emissions from products may be considered to be distributed according to population. However, given that most of the emissions come after the products have been disposed and particularly from landfills, a significant improvement in the spatial disaggregation would be made if the main territorial units were identified according to landfills.

The figures that derive from landfills have to then be combined with the population that uses the specific landfill.

In case landfill locations are not available, population should be used for measuring emissions from all sources.

## **13 TEMPORAL DISAGGREGATION CRITERIA**

Unless better information is available, emissions may be considered to occur evenly throughout the diurnal and annual cycles. However, emissions of mercury are likely to vary with temperature.

## **14 ADDITIONAL COMMENTS**

No additional comments.

## **15 SUPPLEMENTARY DOCUMENTS**

No supplementary documents are required.

## 16 VERIFICATION PROCEDURES

Verification of the emission factors given for the simple methodology should involve the audit-type activities described as the detailed methodology (section 5).

## 17 REFERENCES

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