REPORT

Product-related emissions of Mercury to Air in the European Union

Karin Kindbom John Munthe
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Lars-Gunnar Lindfors
Scientific Director

IVL Swedish Environmental Research Institute

IVL Swedish Environmental Research Institute

Organization

IVL Swedish Environmental Research Institute Ltd.

Address

P.O. Box 5302
SE-400 14 Göteborg

Telephone

+46 (0)31-725 62 00

Report Summary

Project title

Product-related emissions of Mercury to Air in the European Union

Project sponsor

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Author

Karin Kindbom John Munthe

Title and subtitle of the report

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Mercury emissions to air from the use of mercury in products have been estimated for the EU for the year 2005. A simple model for distribution and emissions described in Munthe and Kindbom (1997) has been used with minor modifications. Data on consumption of mercury in the EU in 2005 was obtained from Maxson (2006) and amounted to 125 tonnes in technical products. Estimates of emissions of mercury from dental amalgam were derived from information on cremations in European countries and average contents of amalgam fillings. Annual emissions of mercury to air from product use in EU27 have been estimated to be in the range 10-18 tonnes (best estimate 14 tonnes) from technical products and to 2-5 tonnes from cremation, in total 12-23 tonnes. Of the mercury consumed in technical products, 11% was calculated to be emitted to air, 31% to end up in safe storage while 58% would still be accumulated in society or disposed of in landfills. From the share still accumulated in society, as well as from the already land filled amounts, further emissions of mercury to air may occur in the longer term. Emissions from technical products are calculated based on the consumption of mercury in 2005. Emissions occurring in the same year but caused by consumption in the previous 10 years were derived using the consumption in 2005 and assuming the same patterns of distribution and emissions. The latest available estimates of total anthropogenic emissions of mercury in EU27 refer to the year 2000 and are in the order of 140-190 tonnes, probably to have declined to 2005. Based on these figures the contribution to anthropogenic mercury emissions to air in EU from product use and cremation in 2005 is at least 6-16%. In the previous report (Munthe and Kindbom, 1997) product related air emissions of 72 tonnes were estimated for Europe in the mid 1990´s, corresponding to 18% of the total air emissions. A significant decrease of emissions has thus occurred which is in line with a decreasing use of mercury in technical products, more efficient collection of remaining products and better emission control. However, the calculations show that the use of mercury in products still contributes significantly to total air emissions of mercury in the EU.

Keyword

Mercury, products, emissions

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Foreword

This study was commissioned by the Swedish Chemicals Agency to provide input to on-going discussions on further measures to reduce emissions of mercury to air within the framework of the UN ECE Convention on Long Range Transboundary Air Pollution and UNEP.

Summary

Mercury emissions to air from the use of mercury in products have been estimated for the EU for the year 2005. A simple model for distribution and emissions described in Munthe and Kindbom (1997) has been used with minor modifications. Data on consumption of mercury in the EU in 2005 was obtained from Maxson (2006) and amounted to 125 tonnes in technical products. Estimates of emissions of mercury from dental amalgam were derived from information on cremations in European countries and average contents of amalgam fillings.

Annual emissions of mercury to air from product use in EU27 have been estimated to be in the range 10-18 tonnes (best estimate 14 tonnes) from technical products and to 2-5 tonnes from cremation, in total 12-23 tonnes. Of the mercury consumed in technical products, 11% was calculated to be emitted to air, 31% to end up in safe storage while 58% would still be accumulated in society or disposed of in landfills. From the share still accumulated in society, as well as from the already land filled amounts, further emissions of mercury to air may occur in the longer term.

Emissions from technical products are calculated based on the consumption of mercury in 2005. Emissions occurring in the same year but caused by consumption in the previous 10 years were derived using the consumption in 2005 and assuming the same patterns of distribution and emissions.

The latest available estimates of total anthropogenic emissions of mercury in EU27 refer to the year 2000 and are in the order of 140-190 tonnes, probably to have declined to 2005. Based on these figures the contribution to anthropogenic mercury emissions to air in EU from product use and cremation in 2005 is at least 6-16%.

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1 Background and purpose

Mercury released from intentional use in various products contributes to the anthropogenic emissions of mercury to air and to the long-range transboundary transport.

The emissions to air in Europe from consumption of mercury containing products in the mid 1990´s were estimated by Munthe and Kindbom (1997). The estimates of releases of mercury to air, based on one year's consumption of mercury containing products, amounted to approximately 70 tonnes of mercury annually. Emissions from one years´ consumption were assumed to occur over a time period of 10 years. Annual emissions are thus calculated as the sum of emissions occurring directly from the consumption in the same year, and contributions from consumption in the 10 previous years (assuming the same consumption patterns and amounts). Total anthropogenic emissions of mercury in Europe, compiled from several sources for 1988-1990 were at that time estimated to be in the order of 465-800 tonnes/year. The contribution from product-related mercury to total anthropogenic emissions of mercury in the mid 1990´s was estimated to be around 18%. In the report it was estimated that the releases of mercury from products contributed significantly to the wet deposition input in Scandinavia. The relative amount of the total deposition flux attributable to products was estimated to be 10-14%.

In this report the estimates for product-related releases of mercury to air in the mid 1990´s are updated to present day conditions in the enlarged EU and compared to recently published estimates of total anthropogenic emissions of mercury.

In the previous work emissions of mercury to air from cremation was not quantified. In the present update an estimate of the use of dental amalgam in dentistry and the resulting emissions from cremation in the EU25 is included.

This study was commissioned by the Swedish Chemicals Agency (KemI). The main purpose was to evaluate the contribution of mercury in products to emissions of mercury to air in the European Union.

2 Methodology and previous estimates

The product groups included in the 1997 study were a) batteries, b) measuring and control instruments and c) light sources and electrical equipment. Estimates were made for emissions of mercury during consumption and disposal of these product groups.

Mercury contained in products may be emitted to air while the product is used (consumption) and after disposal when incinerated or when volatilized from landfill. Mercury may also be emitted to air during recycling of scrap metal or when accumulated (stored) in society. Emissions may also occur during production of the metal or of the products, but these emissions are not included in this report.

Emissions of mercury to air from amalgam fillings during cremation are treated and discussed separately in Chapter 4.

2.1 Methodology

In order to estimate the emissions to air of mercury from products, a simplified but systematic approach is necessary for the description of patterns of consumption and disposal of the different product categories. In this study, the estimated annual consumption of mercury in the product category of concern is assumed to be distributed to different "compartments" (i.e. incinerated, land filled, re-collected etc) from which emissions to air occur. The distribution into the different compartments is described using *distribution factors* and the emissions from the compartments using *emission factors*. A schematic diagram of the compartments and emissions of mercury contained in products is given in Figure 1. Separate calculations are made for each of the product groups concerned.

For reasons of calculation, most emissions are assumed to occur within one year from consumption (represented by solid lines in Figure 1). In some cases, *i.e.* mercury released by breaking of products or when products are land filled, the compartment will remain as a source of emissions to air for a longer period of time. These emissions are also accounted for, represented by dotted lines in the figure. The amount accumulated in society (*i.e.* disposed of at a later stage) is assumed to be remobilized once, following the same paths of distribution and emissions as the originally consumed products.

The exact time frame of "early" and "later" emissions of course differs depending on product and its respective average lifetime in society, and the approach should be regarded as a way of generalizing. This general way of calculation was chosen in order to be able to account for the larger part of the air emissions, occurring within a reasonable time period, actually originating from the mercury in products consumed during one year.

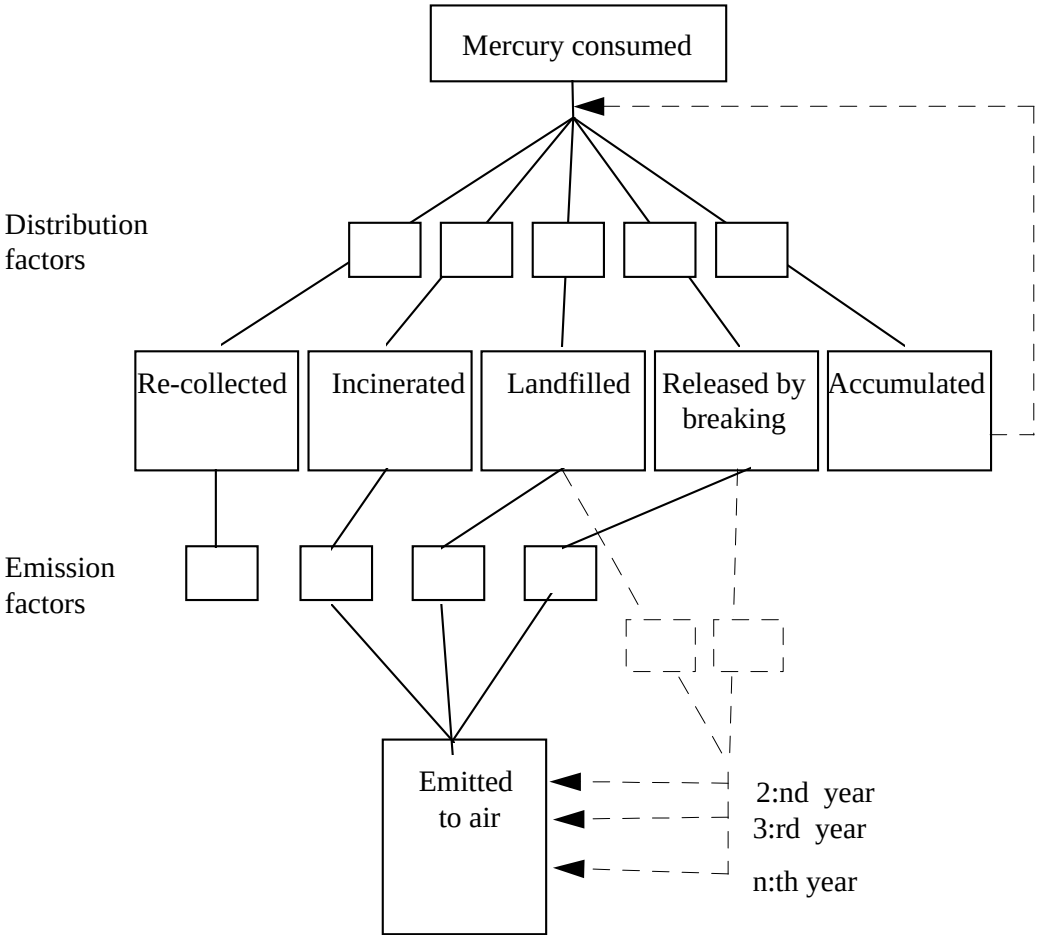


Figure 1 Schematic diagram of the paths of mercury originating in products, resulting in emissions to air.

2.1.1 Compartments

The different compartments used in the calculations are:

- Re-collection: The mercury contained in this compartment is assumed to be re-collected for the purpose of recycling or safe disposal, with no further emissions of mercury to air occurring.
- Incineration: The mercury in this compartment is assumed to be incinerated with household waste under controlled conditions.
- Landfill: The mercury in this compartment is assumed to be disposed of in landfills, without special precautions. Further emissions of mercury to air will occur in the long term.
- Accumulation: The mercury in this compartment is the fraction accumulated in society during or after usage of product, but before it is disposed of. Some products may have a life-time in society of several decades and mercury contained in these products is thus accumulated over time.

- Release by breaking: The mercury in this compartment is the fraction released when products break, accidental spilling etc. This compartment is mainly applicable to products where liquid mercury is contained in glass vessels, *e.g.* thermometers.
- Steel scrap: The mercury in this compartment is the fraction contained in products used as raw material in steel production (electric arc furnace), which applies only to the product group of electrical equipment (not included in Figure 1).

2.2 Previous estimates

A summary of the annual consumption of mercury in products in Europe in the mid 1990´s and the resulting calculated pathways and emissions of mercury are presented in Table 1.

Table 1. Distribution of mercury consumed during one year in Europe in the mid 1990´s (tonnes). (Munthe and Kindbom, 1997)

	Mercury consumed in one year	Emissions to air	Accumulated and land filled*	Safe storage**
Batteries	100	15	59	26
Measuring and control equipment	70	11	46	13
Light sources and el. equipment	230	46	139	45
Sum	400	72	244	84

* Mercury in products still in use or stored in society, and the fraction of mercury land filled. In these cases additional emissions to air occur on a long term basis.
**Safe storage includes re-collected mercury as well as waste from flue gas cleaning etc, assumed to be stored safely.

A follow up on the Munthe and Kindbom (1997) study was made by WS Atkins (1997). Using the same methodology but refining some of the assumptions, especially concerning the Eastern European countries and introducing uncertainty intervals, WS Atkins arrived at total emission estimates from mercury in products where the Munthe and Kindbom study were at the high end (Table 2).

Table 2. Estimated mercury emissions UNECE (tonnes) from consumption (WS Atkins 1997).

	Munthe and Kindbom (1997)	**High** (WS Atkins 1997)	**Medium** (WS Atkins 1997)	**Low** (WS Atkins 1997)
Batteries	15	6	6	1
Measuring and control equipment	11	45	18	3
Light sources and el. equipment	46	25	20	4
Sum	72	76	41	9

3 Present day conditions

3.1 Estimated total anthropogenic emissions of mercury to air in EU-25

Total anthropogenic emissions of mercury in Europe, compiled from several sources in Munthe and Kindbom (1997) for 1988-1990 were at that time estimated to be in the order of 465-800 tonnes/year.

According to the presently available literature the total anthropogenic emissions of mercury in Europe have decreased significantly from 1988 - 1990 until the year 2000.

An emission inventory for the year 2000, based on submissions of emission data from the parties to the UN ECE Convention of LRTAP (www.unece.org/env/), arrive at emissions of mercury to air in EU-25 in 2000 of 190 tonnes (Denier van der Gon et. al., 2005, in Hettelingh et. al., 2006). In the compilation of the inventory, officially submitted emission data "overruled" expert estimates. Possible re-emissions and contributions from uncontrolled or illegal handling of mercury or mercury containing waste were not included.

Time series of anthropogenic emissions of mercury in the EMEP region (Countries within the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe under the Convention on Long-range Transboundary Air Pollution, www.unece.org/env/lrtap/) is presented as in **Figure 2** (Ilyin et al 2006). The estimate for the year 2000 is slightly above 200 tonnes of mercury.

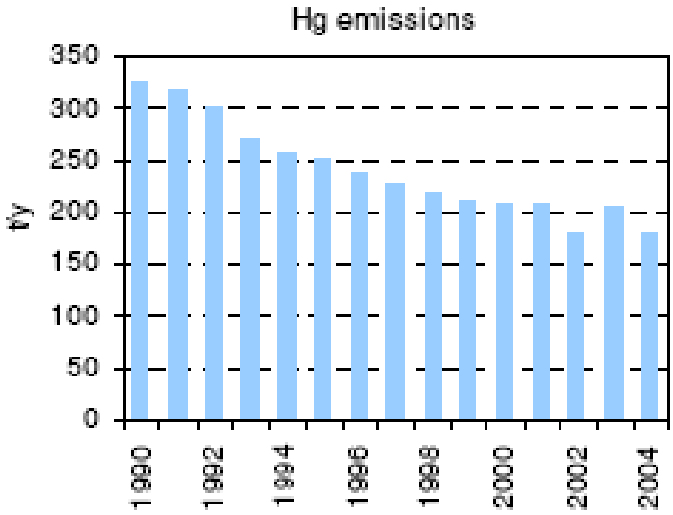


Figure 2. Total anthropogenic emissions of mercury in the EMEP region in the period 1990-2004 according to official data combined with expert estimates (from Ilyin et al 2006).

In the Extended Impact Assessment, Community Strategy Concerning Mercury (Annex 3, Chapter 5) referring Pacyna, 2003 (EC, 2005b) (see also http://espreme.ier.uni-stuttgart.de/) the emissions of mercury in EU 27 was estimated to amount to 141 tonnes in 2000 and 240 tonnes for all of

Europe. Estimates were made by source and were a combination of information from official submissions of data from countries and expert estimates.

From the cited literature above, the total anthropogenic emissions of mercury to air in the EU 25-27 can be assumed to have been in the order of 140-190 tonnes in 2000.

3.2 Estimated consumption of mercury in products in EU-25

The market demand and consumption of mercury in products in EU-25 was estimated by Maxson (2006) to have amounted to 215 tonnes in 2005, and is expected to further decline in the future (Table 3).

Table 3 EU-25 mercury consumption (Maxson, 2006)

EU-25 mercury consumption (tonnes)	2005	2010	2015
Batteries	20	14	8
Dental amalgam	90	83	77
Measuring & control equipment	35	20	15
Lighting	35	30	25
Electrical & electronic devices	35	0	0
	215	147	125

Other uses of mercury estimated by Maxson include the chlor-alkali industry, small-scale gold mining and laboratory and pharmaceutical use.

The following reasoning relating to the estimates for the mercury demand for the different product groups is taken from Maxson (2006).

Batteries: Through 2000 the mercury content in Chinese-manufactured batteries was quite high, but it has been confirmed that most manufacturers have now shifted to lower mercury designs. Still there is significant ongoing trade in mercuric oxide batteries. It is further assumed by Maxson that there remain a large number of button cell batteries containing in the order of 1% mercury, which will be replaced by mercury-free alternatives in the coming years. The mercury content in new alkaline batteries is considered to be quite low.

Dental amalgam: In many EU countries dental use of mercury is declining while in others better access to dental care may increase mercury use temporarily.

Measuring and control equipment, of which 15 tonnes of mercury was consumed in thermometers in 2005. The mercury demand for this product group is expected to decrease. There is also a pending EU directive to phase out the sale and use in certain devices (EC, 2006).

Lighting: The mercury content in low-energy lamps has become lower but more lamps are sold and the availability of alternatives to low-energy lamps containing mercury is still quite limited. The RoHS directive (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment, Directive 2002/95/EC) restricts the use of mercury in electrical and electronic devices, but there are exemptions for certain lamps with some limits for the mercury content (EC, 2002).

Electrical end electronic devices: According to the RoHS-directive, there is a ban on mercury in new electrical and electronic equipment put on the market from 1 July 2006 (EC, 2002).

4 Estimated emissions from mercury containing products and from crematoria

The estimated emissions to air of product-related mercury in this study are derived from the estimated consumption in one year, 2005, and refer to future emissions within an approximate time period of 10 years. Further emissions will occur from this amount of consumed mercury in the longer term, namely from remaining mercury released from broken products and from land filled mercury. Releases will also occur from further redistribution of the accumulated store in society along the paths to the different "compartments" of re-collection, breakage, incineration, landfill or steel scrap. In the calculations, one re-distribution of the initially accumulated store is included in the calculations, but eventually all of the accumulated amount will be re-distributed.

An update of the estimated product-related emissions of mercury has been made using the same methodology as in Munthe and Kindbom (1997), but introducing a split of the former aggregated product group of electrical equipment and light sources into two separate groups. Consumption data were revised according to Maxson (2006) (Table 3), as were the assumed data on recovery/re-collection. Maxson estimates the collection rate of product mercury from the waste stream to be in the order of 20-30 % as a general figure for EU25 (Table 4). The collection rates of mercury vary from nil to well over 50% depending on country and product category, and data are pointed out to be uncertain. According to Maxson (2006) the uncertainty regarding recycled or recovered amounts of mercury in 2005 is believed to be ±30 %.

Table 4. EU25 Hg waste stream and estimated recycling or recovery in 2005 (Maxson, 2006).

	Hg in EU25 waste stream (tonnes)	EU25 Hg recycled or recovered (%)	EU25 Hg recycled or recovered (tonnes)
Batteries	40	25%	10
Dental	72	25%	18
Measuring and control	42	25%	11
Lighting	46	25%	11
Electrical & electronic	42	25%	11
	242		**60**

The mercury in the waste streams is higher than the estimated market demand in 2005 242 tonnes and 215 tonnes respectively. This may indicate that the mercury consumption has declined in EU25.

4.1 Distribution factors

A review and revision of the distribution factors used in the Munthe and Kindbom study from 1997 was made. The distribution factors used in the present calculations are presented in **Table 5**.

The distribution factors are in general uncertain and based on references and assumptions as described in the 1997 study, combined with updated information from WS Atkins (1997). Adjustments considering new information have primarily been made concerning the distribution factors for re-collection/recovery and for waste incineration as described below.

Table 5 Distribution factors

	Re-collected	Release by breaking	Incinerated	Land filled	Accumulated	Steel scrap, smelters
Batteries	0.25	0.01	0.20	0.44	0.10	
Measuring and control eq.	0.25	0.05	0.10	0.25	0.35	
Electrical equipment	0.25	0.01	0.10	0.25	0.34	0.05
Light sources	0.25	0.05	0.10	0.25	0.35	

For the *re-collected/recovered* fraction, the general estimate of 25% from Maxson (2006) was used for all product groups. In the previous study less mercury was assumed to be re-collected.

The distribution factors for *release by breaking* from the 1997 study were generally retained, with only minor adjustments. These fractions are uncertain and based on expert judgement, but were in general considered to be reasonable by WS Atkins (1997). A part of the mercury released by breaking is assumed to leak into cracks etc. at breaking where it cannot be recovered. This mercury will continue to be emitted to air in the longer term, but at an assumed lower rate.

The assumptions concerning the *incinerated* fractions were somewhat revised based on present statistics. An update concerning the fate of municipal solid waste (MSW) in EU27 was made, in order to have a basis on which to allocate distribution factors for product mercury not recovered from the waste stream. According to UN statistics (UNSD/UNEP 2001 and 2004, and OECD/Eurostat 2002), presenting data for the years 2001/2002, it can be derived that in EU27 the fraction of collected MSW incinerated in EU27 in 2001/2002 was at least 15% while approximately 55% of the MSW was land filled, the remainder being recycled or lost via uncontrolled handling. For some countries only the waste incinerated for energy recovery purposes is included in the reported data, why the actual fraction incinerated might be higher. There are large differences between countries and also between Western and Eastern Europe. From the reported data in the statistics the fraction incinerated in Western Europe amount to at least 17% and to at least 3% in Eastern Europe. Furthermore, according to WS Atkins (1997) it could be assumed, at least 10 years ago, that a large fraction of the waste was burnt uncontrolled on bonfires in Eastern Europe. The occurrence of uncontrolled incineration has not been taken into account in the present study.

Based on the UN statistics it has been assumed that approximately 20% of the municipal solid waste is incinerated in EU. For the purpose of the calculations of emissions to air of product related mercury, it has further been assumed that for the most short-lived and wide-spread consumer product, batteries, this fraction of incineration is valid. For the other product groups, electrical equipment, light sources and measuring and control instruments, a lower fraction, or 10% is assumed to be incinerated in the shorter term (~within a year from entering the market). In these product groups there is on the other hand a substantial fraction of the mercury consumed in one year that remains accumulated in society, of which a certain amount will be re-distributed to incineration at a later stage.

The solid waste from flue gas cleaning at MSW incineration is assumed to be stored safely with no further emissions of mercury to air.

For electrical equipment, 5 % of the mercury contained in the products is assumed to be distributed as raw material - *steel scrap* - for steel production. WS Atkins (1997) suggested that this fraction might be somewhat higher, but the distribution factor of 0.05 was retained in view of the lack of more detailed information.

The remaining amounts of consumed mercury in products are distributed to *land filled* and *accumulated* amounts. In general the assumption was made that for the product groups with a life time in society of several years, approximately 35% will be accumulated while 25% will be land filled. Due to the expected shorter life-time for batteries, the accumulated fraction in society is assumed to be lower and the land filled fraction higher. In general the original assumptions from the 1997 study were retained, with some adjustments in the numbers mainly as a result of the increased fractions expected to be re-collected.

4.2 Emission factors

The "initial" (~within a year) emission factors for release of mercury from the individual product groups distributed to the different compartments are presented in **Table 6**. In

Table 7 the emission factors for mercury released by breaking and from land filled products containing mercury for the following years are presented. This fraction of mercury is expected to be more slowly released since it will be partly immobilised by coverage of e.g. new landfill masses if land filled, or dust etc. for the mercury released by breaking/spilling which is assumed no to be collected.

Table 6. Emission factors used in the calculation of "initial" pathways.

	Re-collected	**Release by breaking**	**Incinerated**	**Land filled**	**Accumulated**	**Steel scrap, smelters**
Batteries	0	0.05	0.50	0.005	0	-
Measuring & control eq.	0	0.05	0.50	0.05	0	-
Electrical equipment	0	0.05	0.50	0.05	0	0.90
Light sources	0	0.05	0.50	0.05	0	-

Table 7 Emission factors from remaining mercury released by breaking and from land filled products, annually for the 9 consecutive years.

Emission factors, annually

	Released by breaking	Land filled
Batteries	0.005	0.001
Measuring and control eq.	0.005	0.001
Electrical equipment	0.005	0.001
Light sources	0.005	0.001

Re-collection/recovery

The amount of mercury in products distributed to re-collection/recovery is assumed to be stored safely, not contributing to air emissions. This is not entirely true since at least part of the mercury re-collected will be recycled. In the case of recycling, emissions of mercury to air might occur.

Release by breaking

Assuming the mercury is released by breaking, leakage etc., a general emission factor of 0.05, as given by Ayres (1989) for metallic use, is assumed for all product groups in the calculations

Incineration

Most emission factors, except for incineration, were retained from the 1997 study. The emission factor for incineration was revised from 0.7 down to 0.5. WS Atkins in 1997 suggested an emission factor of 0.5 for Western European conditions but much higher for Eastern European countries at that time. A general emission factor for mercury from waste incineration, which is representative for conditions in the whole of EU is not known with certainty. In order to illustrate the impact on the calculated emissions of mercury to air from the choice of mercury emission factor for waste incineration, alternative calculations were made and are presented together with the results below (Table 9 and Table 10).

Landfill

From some products, like measuring instruments, light sources and some other electrical equipment, the contained mercury may easily be released through breakage or degradation of products, accidental spilling etc. while for others, such as batteries, where the mercury is safely encapsulated, the time lag before any emissions to air occur will be very long. In the calculation of emissions to air, both "early" (i.e. those occurring in the same year as the consumption) and "later" (i.e. those occurring under the following 9 years) emissions are taken into account. Potential emissions occurring more than 10 years after consumption have not been estimated. When recently land filled, the mercury would have a higher evaporation rate than older waste, when some or all of the waste is assumed to have been covered.

For emissions occurring in the same year as consumption, an emission factor of 0.05 is assumed (Munthe and Östlund 1994), equal to the factor applied for releases by breaking. For later emissions the rate is supposed to be lowered by a factor of fifty, giving an emission factor of 0.001. These factors are valid under the assumption that the product is broken when land filled, and applies to measuring and control instruments, light sources and electrical equipment.

For batteries, where the mercury is not so easily released, a lower emission factor of 0.005 is chosen for early emissions while 0.001 is used for batteries as well as for the other product groups in the case of later emissions.

As an example, an emission factor of 0.008 for fluorescent lamps placed in landfill was suggested by NEMA (1997), based on experiments. These experiments included coverage of the land filled lamps for a time period of 20 days.

Steel scrap

In the case of mercury containing products used as scrap in steel production (electric arc furnace), the emissions to air would be at least 90% assuming that no flue gas cleaning efficient for removal of mercury is employed.

4.3 Emissions of mercury to air from products

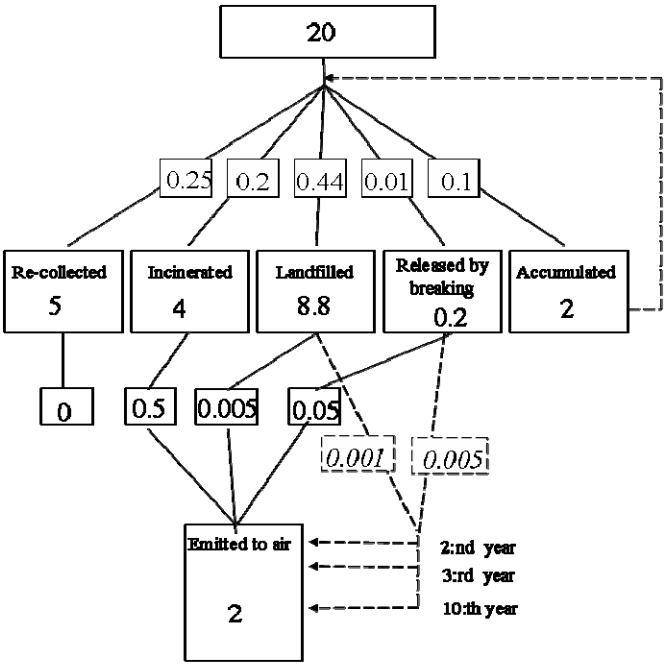
The results of the calculations showing the distribution and emissions to air of mercury consumed in EU25 in 2005 for the product groups batteries, measuring and control equipment, electrical equipment and light sources is presented in **Table 8**. According to the calculations 14 tonnes of the mercury consumed in products in 2005 will be emitted to air within approximately ten years (excl. dental amalgam from crematoria). This corresponds to 11 % of the mercury consumed. 39 tonnes or 31% will have been re-collected and stored safely while 72 tonnes or 58% is land filled or still accumulated in society.

Table 8. Estimated distribution of mercury (tonnes) to air, to accumulation and to safe storage in EU 25 from the consumption of mercury in products in 2005. (Rounded numbers)

	Mercury consumed in one year	**Emissions to air**	**Accumulated and land filled***	**Safe storage****
Batteries	20	2	11	7
Measuring & control eq.	35	3	21	11
Electrical equipment	35	5	19	11
Light sources	35	3	21	11
Sum	125	14	72	39
Fraction of consumed amount		*11 %*	*58 %*	*31 %*

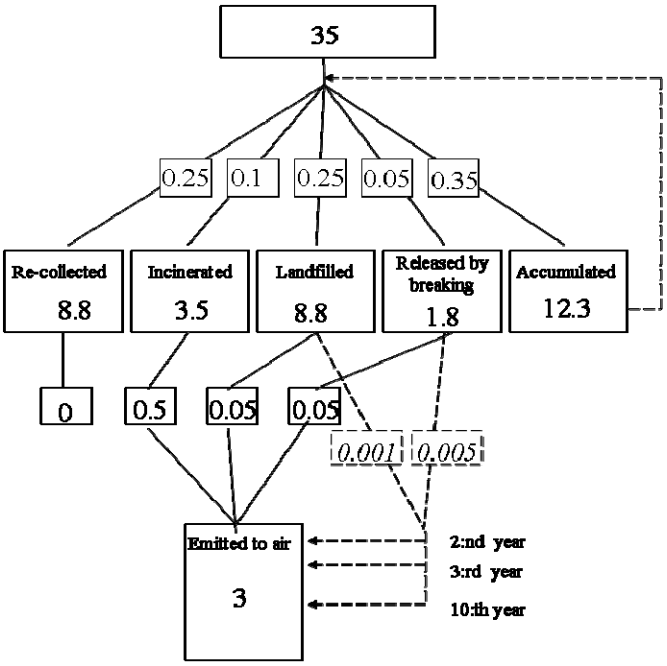
* Mercury in products still in use or stored in society, and the fraction of mercury land filled. In these cases additional emissions to air occur on a long term basis.
**Safe storage includes re-collected mercury as well as waste from flue gas cleaning etc, assumed to be stored safely.

The detailed calculations for each product group are presented in Figures 3 - 6.



Emissions from one year's consumption: 2.1 tonnes
Including redistribution of accumulated store: 2.3 tonnes

Figure 3*Batteries*



Emissions from one year's consumption: 2.4 tonnes
Including redistribution of accumulated store: 3.2 tonnes

Figure 4*Measuring and control equipment*

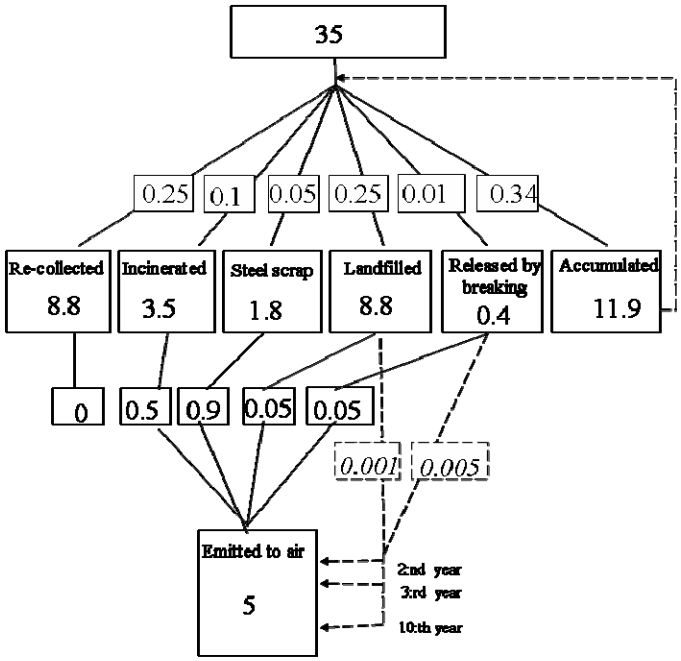


Figure 5*Electrical & electronic devices*

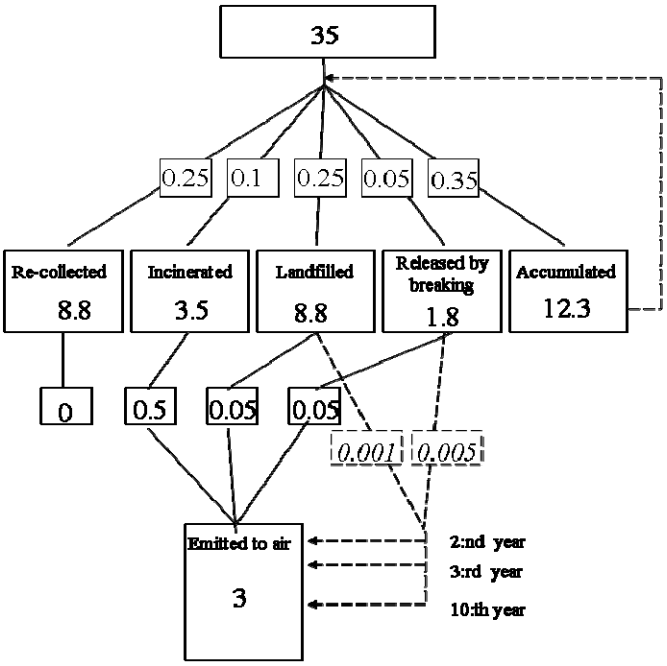


Figure 6*Light sources*

As a sensitivity analysis, and also because additional measures are possible to control mercury emissions from waste incineration, two alternative emission factors for waste incineration were applied. In **Table 8** above, the assumed general emission factor for mercury from waste incineration in EU25 is 0.5, which means that 50% of the mercury in the waste will be emitted to air. To illustrate the impact of the choice of emission factor on the calculated emissions, emission factors of 0.3 and 0.7 were applied (30% or 70% of the mercury in the waste will be emitted).

Table 9. Estimated distribution of mercury (tonnes) to air, to accumulation and to safe storage in EU 25 from the consumption of mercury in products in 2005. Alternative emission factor for incineration, 0.3. (Rounded numbers)

Emission factor for incineration 0.3	Mercury consumed in one year	Emissions to air	Accumulated and land filled*	Safe storage**
Batteries	20	1	11	8
Measuring and control eq.	35	2	21	11
Electrical equipment	35	4	19	11
Light sources	35	2	21	11
Sum	125	10	73	42
Fraction of consumed amount		*8 %*	*59 %*	*33 %*

Table 10. Estimated distribution of mercury (tonnes) to air, to accumulation and to safe storage in EU 25 from the consumption of mercury in products in 2005. Alternative emission factor for incineration, 0.7. (Rounded numbers)

Emission factor for incineration 0.7	Mercury consumed in one year	Emissions to air	Accumulated and land filled*	Safe storage**
Batteries	20	3	11	6
Measuring and control eq.	35	4	21	10
Electrical equipment	35	6	19	10
Light sources	35	4	21	10
Sum	125	18	72	36
Fraction of consumed amount		*14 %*	*57 %*	*29 %*

The total amount of mercury emitted to air from product use is thus estimated to be in the range 10 to 18 tonnes annually, excl. dental amalgam, with best estimate 14 tonnes. The main uncertainty is the selection of emission factor for waste incineration which is the largest source for product-related emissions of mercury to air within a time period of approximately 10 years from the year of consumption. In the previous report (Munthe and Kindbom, 1997) total product-related air emissions of 72 tonnes were estimated for Europe in the mid 1990´s. A significant decrease has thus occurred which is in line with a decreasing use of mercury in technical products, more efficient collection of remaining products and better emission control. The emission value estimated in this study, 14 tonnes, corresponds to at least 7-10% of the total emissions of mercury to air in EU25, which in 2000 were in the order of 140-190 tonnes, probably to have declined further.

In the previous study (Munthe and Kindbom, 1997) the product-related emissions were estimated to contribute to the wet deposition in Sweden by 10-14% based on source-receptor date from atmospheric modelling from the mid 1990´s. Since then, overall European mercury emissions have decreased whereas increases have occurred globally. This has led to a changed pattern of distribution and deposition of mercury over Europe. Global emissions and distribution can thus contribute a larger fraction of the deposition in Europe in comparison to the situation in mid 1990´s. This effect is more pronounced in regions far away from the main source regions in central

Europe. The product-related emissions in Europe are thus expected to contribute a smaller amount in remote regions in comparison to more central areas.

4.4 Mercury in dental amalgam and emissions to air from crematoria

According to Maxson (2006) the market demand for mercury in dental amalgam was 90 tonnes in EU25 in 2005, which is the second largest use of mercury in EU25 after the chlor-alkali industry (190 tonnes in 2005).

Some Member States identify dental amalgam as a significant source of mercury releases, including via dental surgeries and cremation (EC 2005, COM(2005) 20 final). Treatment of dental amalgam waste is covered by Community waste law. Emissions from crematoria are not covered by Community law, but are regulated in several Member States (EC, 2005a). Several countries are committed to an OSPAR recommendation 2003/4, which requires applying BAT (Best Available Technology) to crematoria, with an anticipated reduction of emissions of mercury to air of > 90%. In the OSPAR Recommendation on cremation, parties were due to submit a first implementation report on estimated mercury releases by 30 September 2005, and a second report by 30 September 2009.The reports from 9 countries in 2005 (OSPAR, 2006) show that most Contracting Parties have regulations which control the emissions of mercury from crematoria and that a significant number of crematoria already apply mercury removal techniques. Furthermore, in a number of the countries there exist specific mercury emission standards for new plants as well as remediation programmes for existing crematoria, which will lead to further reduction of mercury emissions.

Several methods are reported for calculating loads emitted from crematoria in the 9 countries covered in the OSPAR (2006) report. The most common is to use an estimate for the amount of mercury in the fillings of each body and multiply this by the number of cremations. The estimated amount of mercury in the fillings of each body ranges between 1 and 5 g. Some countries then apply an abatement factor to account for the amount of mercury which is removed during cremation. Several countries which have mercury measurement devices for flue gases calculate the mercury directly from these measurements based on the time the crematoria is operating. Some Contracting Parties gave very clear figures for loads, whereas others were less precise. Therefore on the basis of the information provided it was not considered possible to provide a reliable figure for the total load of mercury emitted from the crematoria of those Contracting Parties who reported. A very rough and provisional estimate was around 1 tonne for the 9 countries covered (OSPAR, 2006). Scaling these figures up to cover EU27 on the basis of population sizes would give a rough total emission estimate of around 2 to 3.5 tonnes per year (EC, 2005b). There are, however, cultural issues on cremation, which is most common in Northern Europe while in other countries it is rarely practiced, and in Greece cremation is forbidden. The type of cremation installations also varies (EC, 2005b).

Based on international cremation statistics for 2004, published by the Cremation Society of Britain (2007), rough estimations of emissions of mercury from cremation in Europe can be made. The statistics gives the number of crematoria and the number of cremations per country. Two alternative calculations based on assumed amounts of mercury per cremation were made, 1 and 5 g Hg respectively (OSPAR, 2006). The calculated emissions of mercury based on information on the number of cremations from 19 European countries amount to 1 and 4.8 tonnes respectively, assuming no flue gas cleaning. Some countries were only covered in the statistics by the number of crematoria. To make a rough estimate to cover also those countries (6 additional countries), the

calculated average number of cremations/crematoria from the 19 countries where this information was available was used to estimate total numbers for 25 EU-countries. The calculated emissions of mercury to air in this case amounted to 1.3 and 6.7 tonnes respectively. There is flue gas cleaning installed in crematoria in some countries, but the extent of this practice in the whole of EU is not known.

An analysis in 2002 suggested a total emission of mercury to air from cremation in EU15 plus Poland, the Czech Republic and Slovenia of about 3 tonnes of mercury per year (RPA, 2002).

As a summary of the above, it seems reasonable to assume that the annual emissions of mercury to air from cremation in EU27 are in the order of 2 - 5 tonnes/year.

4.5 Results from other recent studies

Product related emissions have also been calculated for the USA (Cain et al, 2007). For the year 2000, an estimated 41 tonnes from "intentional use in products" are emitted to air corresponding to 32% of the total US emissions of mercury. Emissions decreased from 221 tonnes in 1990 and from 41 to 26.9 tonnes between 2000 and 2005.

Emissions to air may occur from several steps in the life-cycle of mercury in dental amalgam. Apart from emissions to air from cremation, which is the only source considered in this report, emissions may also occur at production of amalgam, as direct emissions from dental clinics and from different steps in the waste stream. Maxson (2007) estimated the total emission to air from use and disposal of dental amalgam in the EU to be 23 tonnes including cremation i.e. considerably higher than the amount emitted from cremation alone.

5 Conclusions

Annual emissions of mercury to air from product use in EU27 have been estimated to be in the range 10-18 tonnes (best estimate 14 tonnes) from technical products and to 2-5 tonnes from cremation, in total 12-23 tonnes. Emissions from technical products are calculated based on the consumption of mercury in 2005. Emissions occurring in the same year but caused by consumption in the previous 10 years were derived using the consumption in 2005 and assuming the same patterns of distribution and emissions. Further emissions to air will occur also in the longer term since a considerable share of the mercury consumed in one year in technical products will still be accumulated in society after 10 years or already disposed of in landfills where further leakage occurs. The amount of mercury accumulated in products in society will eventually be disposed of and the mercury will be recovered or released from incineration or landfills.

The latest available estimates of total anthropogenic emissions of mercury in EU27 refer to the year 2000 and are in the order of 140-190 tonnes, and may have declined further until 2005. Based on these figures the contribution to anthropogenic mercury emissions to air from product use of 12-23 tonnes, including from cremation, calculated for years around 2005 would be at least 6-16%.

In the previous report (Munthe and Kindbom, 1997) product related air emissions of 72 tonnes were estimated for Europe in the mid 1990´s, corresponding to 18% of the total air emissions. A significant decrease of emissions has thus occurred which is in line with a decreasing use of mercury in technical products, more efficient collection of remaining products and better emission control.

However, the calculations show that the use of mercury in products still contributes significantly to total air emissions of mercury in the EU.

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