European Commission
Directorate-General Environment

Contract: ENV.G.2/ETU/2007/0021

Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society

FINAL REPORT

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Summary

Mercury and its compounds are highly toxic to humans, ecosystems and wildlife. A key aim of the Community Strategy Concerning Mercury is to reduce mercury levels in the environment and to reduce human exposure. The European Community has already taken a range of measures to reduce mercury emissions and uses, but still more remains to be done. With the goal of constructing and maintaining an overarching and integrated community-wide framework to properly manage mercury and adequately control its adverse environmental impacts, the community strategy describes a range of actions for reducing emissions, reducing supply and demand, and addressing surpluses and reservoirs of mercury.

This study strengthens the foundation for further policy decisions by providing:

- an overview of current use of mercury for processes and in products in the European Union, and of mercury accumulated in society in products, at production facilities, on the grounds of contaminated sites and within other stocks and inventories;
- an overview of the waste handling situation and recycling paths in the EU, as well as of national legislation that goes beyond current EU legislation; and
- an assessment of options for reducing major inputs of mercury to society in dental amalgams, measuring equipment, mercury catalysts in polyurethanes and mercury porosimetry.

Current use of mercury in products and processes
A detailed split of EU mercury consumption among 41 product groups is shown in Table 0-1 below. In total, more than 60 mercury applications have been assessed in the study. The estimates are based on new information obtained from market actors (personal communications, sector-specific queries and organisations' websites), statistics and a comprehensive questionnaire to Member States, Norway and Switzerland (EU27+2).

Mercury "consumption," as defined for the purposes of this assessment, and dependent on the area of application, refers to:

- the quantity of liquid mercury applied during the year in question for industrial processes (e.g. chlor-alkali) or laboratory analyses;
- the quantity of liquid mercury used during the year in question for maintenance of equipment (e.g. lighthouses); or
- the mercury content of products (e.g. batteries) marketed in the EU during the year in question, i.e., domestic production plus imports less exports.

Inevitably there are some gray areas where these basic definitions are inadequate to cover complex mercury flows; however, these definitions have proven to be fully adequate for the objectives of this research within the ranges of uncertainty, as noted.

The results of this study are compared with previous estimates of mercury consumption in section 2.9. The comparison reveals that for some of the application areas that have been addressed by existing EU legislation – especially measuring equipment, switches and relays – mercury consumption has decreased significantly in recent years, whereas mercury consumption for other major application areas, e.g. chlor-alkali production and dental amalgams, has been more stable.

Table 0-1 Mercury consumption in industrial processes and products in the EU with an indication of the level of substitution (2007)

Application area	Mercury consumption Tonnes Hg/year	Percentage of total	Level of substitution
Chlor-alkali production *2	**160 - 190**	**41.2**	
Light sources	**11 - 15**	**3.1**	
Fluorescent tubes	*3.3 - 4.5*	*0.9*	*0*
Compact fluorescent tubes	*1.9 - 2.6*	*0.5*	*1*
HID lamps	*1.1 - 1.5*	*0.3*	*0*
Other lamps (non electronics)	*1.6 - 2.1*	*0.4*	*1*
Lamps in electronics	*3.5 - 4.5*	*0.9*	*1*
Batteries	**7 - 25**	**3.8**	
Mercury button cells	*0.3 - 0.8*	*0.1*	*2*
General purpose batteries	*5 - 7*	*1.4*	*4*
Mercury oxide batteries	*2 - 17*	*2.2*	*4*
Dental amalgams	**90 - 110**	**23.5**	
Pre-measured capsules	*63 - 77*	*16.5*	*2*
Liquid mercury	*27 - 33*	*7.1*	*3*
Measuring equipment	**7 - 17**	**2.8**	
Medical thermometers	*1 - 3*	*0.5*	*3*
Other mercury-in-glass thermometers	*0.6 - 1.2*	*0.2*	*3*
Thermometers with dial	*0.1 - 0.3*	*0*	*4*
Manometers	*0.03 - 0.3*	*0.04*	*4*
Barometers	*2 - 5*	*0.82*	*3*
Sphygmomanometers	*3 - 6*	*1.1*	*3*
Hygrometers	*0.01 - 0.1*	*0.01*	*3*
Tensiometers	*0.01 - 0.1*	*0.01*	*4*
Gyrocompasses	*0.005 - 0.025*	*0.004*	*3*
Reference electrodes	*0.005 - 0.015*	*0.002*	*3*
Hanging drop electrodes	*0.1 - 0.5*	*0.1*	*3*
Other uses	*0.01 - 0.1*	*0.01*	
Switches, relays, etc.	**0.3 - 0.8**	**0.1**	
Tilt switches for all applications	*0.3 - 0.5*	*0.09*	*4*
Thermoregulators	*0.005 - 0.05*	*0.01*	*4*
Read relays and switches	*0.025 - 0.05*	*0.01*	*3*
Other switches and relays	*0.01 - 0.15*	*0.02*	*4*
Chemicals	**28 - 59**	**10.2**	
*Chemical intermediate and catalyst (excl PU) *1*	*10 - 20*	*3.5*	*2*
Catalyst in polyurethane (PU) production	*20 - 35*	*6.5*	*3*
Laboratories and pharmaceutical industry	*3 - 10*	*1.5*	*3*
Preservatives in vaccines and cosmetics	*0.1 - 0.5*	*0.1*	*3*
Preservatives in paints	*4 - 10*	*1.6*	*4*
Disinfectant	*1 - 2*	*0.4*	*4*
Other applications as chemical	*0 - 1*	*0.1*	*3*
Miscellaneous uses	**15 - 114**	**15.2**	
Porosimetry and pycnometry	*10 - 100*	*12.9*	*2*
Conductors in seam welding machines (mainly maintenance)	*0.2 - 0.5*	*0.1*	*3*
Mercury slip rings	*0.1 - 1*	*0.1*	*N*
Maintenance of lighthouses	*0.8 - 3*	*0.4*	*0*
Maintenance of bearings	*0.05 - 0.5*	*0.1*	*0*
Gold production (illegal)	*3 - 6*	*1.1*	
Other applications	*0.5 - 3*	*0.4*	
Total (round)	**320 - 530**	**100**	

[See notes on next page]

Notes to Table 0-1:

*1 In order to avoid double counting, the mercury used as chemical intermediates and catalysts (excluding PU elastomers) is not included when calculating the total.

*2 Represent the amount added each year to the cells including of which a part is recycled internally within the plants.

Key to assigned substitution level indices:
0 No substitution indicated in assessed data sources; development often underway
1 Alternatives are ready to be marketed, or are present on the market but with marginal market share
2 Alternatives are being marketed and have significant market share, but do not dominate the market
3 Alternatives dominate the market, but new products with mercury also have significant market share
4 Mercury use is fully, or almost fully, substituted
N Not enough data was found to assign an indicator

The study has quantified the mercury use for some significant applications of mercury that have drawn less attention until now:

- Mercury lamps used for backlighting in electronics displays;
- Mercury batteries for applications exempted from the Battery Directive;
- Mercury catalysts in the production of polyurethane elastomers;
- Mercury biocides in paints;
- Mercury use in porosimetry;
- Mercury used for the maintenance of lighthouses.

In particular, the large consumption of mercury catalysts for production of polyurethane elastomers, where the catalysts end up in the final product in concentrations of about 0.2% mercury, is a new finding that calls for attention.

Another large application area, porosimetry, has until now escaped notice. The actual mercury quantities used are uncertain, but it is quite certain that mercury consumption for this application is higher than the consumption for some of the application areas that have been in focus for policy-makers.

With regard to another interesting finding, it has been generally accepted that mercury biocides were phased out in European paint production, but this study has revealed that significant amounts are still used within the EU. While this application is regulated by the Biocide Directive, a Member State may, for a period of 10 years from the date of transposition, continue to apply its current system or practice of placing biocidal products on the market.

Level of substitution

The indicated level of substitution in Table 0-1 is for purposes of the overview only. A more detailed treatment of substitution level for the different applications, and an indication of specific applications for which substitution is particularly difficult, is provided in the sections on alternatives for each application area in Chapter 2. In addition, an indication of substitution level by application area in 9 Member States and Switzerland, based on submissions from these countries, is presented in Annex 1.

Manufacturers of mercury-containing products in the EU27+2

Production of mercury-containing products in the EU has been assessed for all major applications, and a summary list of identified manufacturers is presented in section 2.9. In total about 60 manufacturers of mercury-containing products in the EU have been identified. The list is not considered complete, but is assumed to include the major manufacturers for most product categories. The companies range from small family-owned workshops to major companies in the electrical and electronics sector, with the majority of the companies being small to medium sized enterprises.

Besides these companies manufacturing mercury-containing components or end products, a large number of companies use mercury-containing components for manufacturing other components or end products. Mercury-wetted reed switches are, for example, manufactured by one company only, but the switches are used by at least six manufacturers in the EU for production of mercury reed relays and switching components, and these components are further used by a large number of manufacturers of electronic equipment. Likewise, a large number of companies are likely to be involved in production of polyurethane elastomers or paints that contain mercury compounds applied as catalysts or biocides, respectively. Although not specifically counted for this study, the number of EU manufacturers currently using mercury-containing components and mercury chemicals appears to be at least several hundred, and perhaps more than one thousand.

Mercury stocks

As presented in Table 0-2, in total about 1,800 tonnes of mercury are estimated to be accumulated in products in use in society, representing about 5 % of the total mercury stock in society and in highly contaminated sites. The detailed split among application areas (summarised in section 2.9) shows that dental amalgams and mercury compounds in polyurethane account for more than 80% of the total accumulated in products in the EU. Previous studies have suggested larger amounts of mercury accumulated in products, but the steep decline in the use of mercury for many product types has also resulted in a decline in the accumulated amounts. Mercury use in chlor-alkali production, either as active mercury in the cells, or as stocks and easily recoverable mercury, accounts for the majority of mercury accumulated in the EU. The study demonstrates that a large amount of mercury may be accumulated in contaminated sites, but it should be noted that the estimate comes with significant uncertainties, and it is doubtful whether much of this mercury could be recovered at a reasonable cost. It is roughly estimated that only some 100-500 tonnes of the accumulated mercury in contaminated sites – apart from chlor-alkali sites – may be readily recoverable.

Table 0-2 Stocks of mercury in EU27+2 society (2007)

Mercury stock, inventory or reservoir	Accumulated Tonnes Hg	Percentage of total
Chlor-alkali production, active	10,900	32
Chlor-alkali production, stock and easily recoverable	2,200	6
Chlor-alkali production, waste and site contamination	11,000	32
In products in use	1,800	5
On shelves in schools and laboratories	180	1
In drains in schools and laboratories	100	0.3
In highly contaminated sites (apart from chlor-alkali)	4,500	13
Stocks by suppliers	3,200	9
Total stocks (round)	34,000	100

The total recovery of by-product mercury from non-ferrous metals production in 2006 is estimated at 40-60 tonnes, while approximately 25-30 tonnes were recovered from gas purification catalysts, sludges, etc., resulting in a total of 65-90 tonnes of mercury recovered as by-product. The total mercury content of all non-ferrous ores refined in the EU27+2 is estimated to be on the order of 300-370 tonnes annually, indicating a significant potential for increased recovery of by-product mercury.

Waste management and recycling paths

The study includes a detailed analysis of the mercury waste management situation. For the applications and products for which specific waste management infrastructure exists, reliable information concerning the EU-wide waste management situation has been collected. This applies to waste from chlor-alkali, batteries, light sources and components of electrical and electronic equipment. For the remaining applications, less complete information has been assessed, and the analysis has necessarily relied more heavily on the reported experiences of fewer countries.

An overview of mercury quantities ending up in waste is presented in Table 0-3. The major sources of mercury in waste, as well as the major sources of mercury recovered from waste, are chlor-alkali production and dental amalgam. The overall recycling efficiency for all mercury waste ranges around 25%. The remaining waste is mainly disposed of in landfills or hazardous waste storage sites. It should be noted that the collection efficiency would be higher than the indicated recycling efficiency, as mercury is not recovered from all the collected waste.

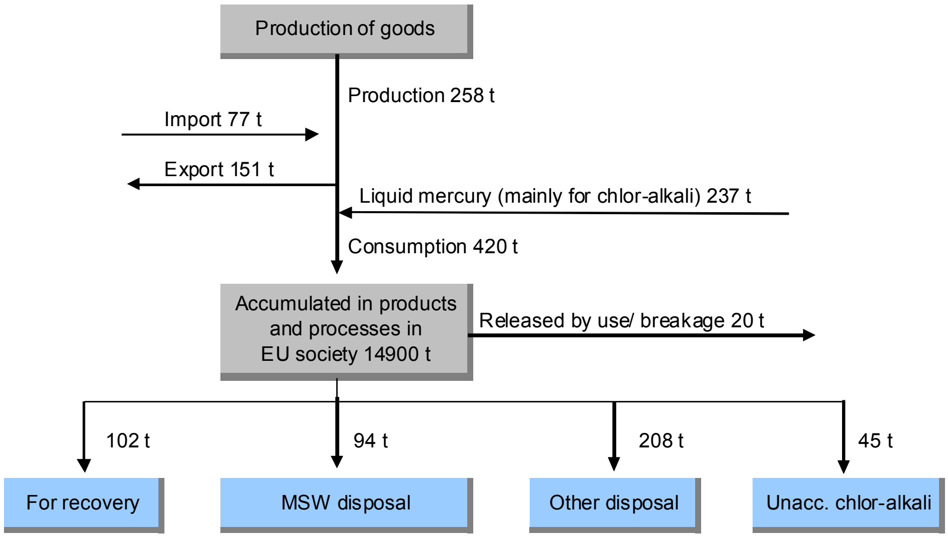
The numbers in Table 0-3 represent the midpoints of varying ranges of uncertainty. For example, the recycling rates for measuring equipment and miscellaneous uses represent more uncertainty than other categories due to the diversity of products and uses. Relatively low recycling rates were found for light sources, batteries and mercury compounds (“chemicals”). All of the latter are characterised by a waste stream with a relatively low mercury concentration. For compounds, the low collection rate is due in particular to the fact that no specific collection or mercury recovery takes place for mercury-containing polyurethane and paints, the major application areas for mercury compounds. Note that recycling rates are generally lower than collection rates, because some collected mercury containing waste may be landfilled/deposited and not recycled.

Table 0-3 Mercury in waste from intentional uses of mercury in EU27+2 society

Products category	Quantities ending up in waste Tonnes Hg/year	Quantities recycled Tonnes Hg/year	Contribution to total amount recycled, %	Recycling efficiency within category and totally, %
Chlor-alkali production	119	35	34	29
Light sources	14	1.6	2	11
Batteries	30	4	4	13
Dental amalgams	95	30	29	32
Measuring equipment	21	4.5	4	21
Switches, relays, etc.	14	7	7	50
Chemicals	41	6.5	6	16
Miscellaneous uses	70	13	13	19
Total (rounded)	404	102	100	25

The overall mercury mass balance for EU27+2 is shown in Figure 0-1 below. The figures represent medium estimates and in particularly the inflow of liquid mercury to processes is very uncertain due to the wide range (10-100 tonnes) of the estimate of the quantities used for mercury porosimetry.

Figure 0-1 Mercury mass balance for EU27+2 society (medium estimates), all figures in tonnes/year.



National legislation going beyond current EU legislation
Only three Member States and Norway have reported having broad national legislation on the use of mercury that exceeds the current EU legislation. Norway has introduced a general prohibition on production, import, export, sale and use of mercury and mercury compounds that entered into force on 1 January 2008. Norway's regulation does not address products covered by existing EU legislation, and provides a few general exemptions until 31 December 2010. The extensive prohibition clearly indicates that viable (but not necessarily cost-effective) alternatives are available for virtually all applications not already addressed by the EU legislation.

Of the Member States, Denmark and the Netherlands have a general prohibition on import, export and sale of mercury and mercury-containing products, but a wide range of products with mercury, under exemptions, are permitted in both countries. Sweden has a prohibition on production, sale and export of thermometers and other measuring equipment, level switches, pressure switches, thermostats, relays, circuit breakers and electrical contacts, but has a few exemptions within these application areas. Sweden intends to enforce a general prohibition in the near future.

Assessment of policy options
On the basis of the analysis of current inputs of mercury to society, and the management of mercury waste, four applications of mercury were selected for a more detailed review of the main impacts resulting from a range of possible further policy measures:

- Dental amalgams (including mercury input and waste management);
- Measuring devices for professional uses (including a detailed assessment of thermometers, barometers and sphygmomanometers);

- Mercury catalysts for polyurethane elastomers; and
- Mercury porosimetry.

In the selection of policy options for these product groups, it was taken into consideration that further measures concerning mercury-containing light sources are already under evaluation in the context of the RoHS Directive. The same is true for mercury-containing components in electrical and electronic medical devices, and monitoring and control instruments.

Benefits of reduced mercury uses and releases

The main benefits accruing from reduced mercury uses and releases outlined in the various policy options are related to human health impacts, environmental impacts and waste management impacts.

A reduction of the input of mercury to society would result in reduced mercury exposures and reduced emissions to the environment over both the short and the long term. The health benefits of various policy options have not been assessed in this study, although some benefits due to reduced mercury emissions have been estimated in recent research carried out in the USA. That research calculated health benefits equivalent to €4,000-110,000 per kg reduction in atmospheric mercury emissions. A recently published study from the Nordic Council of Ministers apply a cost of approximately $12,000 per kg mercury emitted and the benefits of reducing the emissions would consequently be of same magnitude. Direct costs of releases to water were not estimated in these studies, but must be at least in the same order of magnitude, as human exposure to mercury in the environment would to a large extent be via fish. This range of benefits is not directly comparable to reduced use of mercury in products, for which atmospheric emissions (even long-term emissions from landfills and deposits) are much lower than the total mercury content, some product emissions are to water, occupational and other exposures during use or breakage play a role, etc. Nevertheless, it provides a useful range for comparison, especially as environmental benefits are increasingly considered to be of the same order of magnitude as health benefits, but very difficult to quantify.

With regard to benefits associated with reduced management of mercury-containing waste, for all applications described above there are some clear benefits, but for measuring equipment these benefits are assumed to be relatively modest as most alternatives would also require some special treatment (e.g. as electronic waste).

Options for reducing mercury input from dental amalgam, and improving related waste management

Dental amalgam represents the major application of mercury in products in the EU27+2. A general ban on mercury in dental fillings would reduce the total mercury input to society by 80-110 tonnes per year. This study's analysis of the impacts and costs/benefits of such a general ban on the use of mercury indicates a substantial cost associated with the substitution of dental amalgam by composite fillings, the most widely used alternative today. For the EU27+2, total additional costs to dental customers are estimated at €1,000-10,000 million per year, corresponding to €11,000-78,000 per kg reduction in Hg use, or €2-20 per capita per year. The higher price of alternatives is mainly due to the fact that the placement of the fillings often takes longer, whereas the material costs account for only 5-10% of the treatment costs, irrespective of the type of material. It should be noted, however, that if one were to accept these extra costs over 10-12 years – the lifetime of a typical amalgam filling – most fillings in the EU27+2 would then have been replaced by mercury-free alternatives. At this point adverse impacts on health or the environment from this source would no longer be a major concern. Compared to other initiatives that have been adopted to deal with mercury in the environment, a general ban on dental mercury would thus have a very large impact over a quite reasonable period of time.

In any case, extra costs to dental customers should be compared with a number of benefits. For example, expected benefits from reduced adverse effects of mercury releases, and reduced costs for mercury waste management in all associated flows of dental mercury in society appear to be very significant. However, these benefits – and especially the health benefits – are complicated to quantify, depending on various assumptions, and typically present a range that is so wide as to be little more than indicative. For this reason the study has looked more closely at the cost effectiveness of various policy options.

The cost of mercury flue gas controls on crematoria, for reducing the emission of mercury from the dental fillings in cremated bodies, is estimated at approximately €17,000 per kg reduction in Hg release, which is roughly similar to the lower estimate of the cost of substitution of dental amalgam.

Dental amalgam waste represents the major source of mercury input to wastewater in many Member States. The analysis of the impacts and costs of obligatory installation of high-efficiency amalgam separators in dental clinics show that costs would be in the range of €1,400-1,800 per kg reduction in Hg releases. It is evident that installing high efficiency filters and keeping them properly maintained are very cost-effective measures, with a cost per kg reduction in mercury releases of only one-tenth the cost of reducing mercury releases from crematoria.

In the medium term, a general ban on mercury in dental fillings would greatly reduce the need for amalgam separators in dental clinics, and mercury filters on crematoria. In the near term, however, because of the large quantities of mercury already accumulated in the teeth of the population, society does not have the luxury of choosing between substitution and “end-of-pipe” measures. Rather, both need to be applied in parallel.

Options for reducing mercury input from measuring devices used in professional applications
For measuring devices used in professional applications, two policy options were evaluated: to extend the ban on liquid mercury in measuring devices in 76/769/EEC so as to 1) include placing on the market of measuring devices for use in the medical sector; or 2) include all measuring devices for professional use. These options would reduce the mercury input to society by 3-6 or 3.4-7.1 tonnes Hg/year, respectively. Use of measuring devices for research and development, and analytical purposes, would be included in the general exemption in 76/769/EEC.

- Sphygmomanometers
A ban on marketing of measuring devices for the medical sector would, in practice, affect only the market for mercury sphygmomanometers. Alternatives to mercury sphygmomanometers are readily available and represent about 90% of the EU market for manual sphygmomanometers. Mercury sphygmomanometers are still used mostly by general practitioners. According to European manufacturers of mercury-free sphygmomanometers, the best alternatives are as reliable as the mercury devices, while some alternatives are less reliable due to their sensitivity to shock.

The costs to users over a five-year period have been estimated for 1) the mercury sphygmomanometer, 2) a shock-proof aneroid sphygmomanometer of similar price, and 3) a high-end electronic sphygmomanometer. It is evident that the total cost of substitution is very sensitive to assumptions regarding calibration, as the cost of calibration, if undertaken by a service company over a 5-year period, may be considerable. For cheap shock-sensitive aneroid sphygmomanometers (not included in this table), the need for calibration every six months in fact causes such equipment to be the most costly alternative.

The impacts of a marketing ban on manufacturers of sphygmomanometers in the EU are estimated to be insignificant as all manufacturers of mercury sphygmomanometers also manufacture mercury-free alternatives.

The main reason general practitioners hesitate to replace mercury sphygmomanometers with alternatives is that mercury sphygmomanometers by tradition have been considered more reliable, and many general practitioners are reluctant to replace the well-known equipment with new types of equipment. This reluctance is reinforced by the fact that the international and national societies on hypertension still mention the mercury sphygmomanometer as the “gold standard”, although these days the term is often put in quotation marks. There is a need for clearer statements distinguishing between the different types of alternatives, especially e.g. to better differentiate between devices that comply with all international protocols, and less reliable equipment.

If some specialised cardiology departments may still be obliged to use mercury devices in some research programmes in order to ensure that new data are comparable to previous studies, this application would most likely be covered by the general exemption in Council Directive 76/769/EEC.

- Thermometers

Compared to the sphygmomanometer, an assessment of thermometers is more complicated due to the fact that a wide variety of thermometers are used for a range of applications. About half of the mercury in thermometers is used in laboratories, which most likely would be covered by the general exemption in Council Directive 76/769/EEC., while the other half is used for monitoring in industry and some special applications. It could be anticipated that an extension of the ban on liquid mercury in measuring devices would include industrial mercury-in-glass thermometers measuring at 1°C resolution, but a more detailed assessment would be necessary to identify the specific applications of thermometers of higher resolution that should be included, as all measurements undertaken in accordance with national and international standards would probably be exempted, at least initially. For the higher resolution applications, the alternatives are typically ten times the price of mercury thermometers, although the alternatives tend to have more features than the mercury thermometers.

For this reason only an indicative calculation for industrial thermometers can be provided. It is roughly estimated that 50,000 to 100,000 thermometers would be substituted. Considering the range in price of the substitute thermometers, it is estimated that the extra cost would be €15-60 per thermometer. Under these assumptions, the total cost to users in the EU would be €750,000-6,000,000 per year, corresponding to €5,000-20,000 per kg mercury substituted. It should be noted that for many of the thermometers already phased out, the price of alternatives has not been significantly higher than the price of the mercury thermometers, because competitively priced alternatives have generally been available for these applications. A ban would negatively impact a number of small and medium-sized companies as the electronic alternatives are typically not manufactured by the same companies as the mercury devices.

These calculations clearly demonstrate that the cost of substituting one kg of mercury in thermometers is significantly higher than substituting mercury in sphygmomanometers, even when the sphygmomanometers are substituted with the more expensive electronic equipment.

- Barometers

The impact of a ban on the marketing of liquid mercury in measuring devices in 76/769/EEC is expected to have a very limited impact on both manufactures and users of barometers although a few small manufacturers may be negatively impacted. The use of mercury barometers for professional applications has more or less already been phased out due to the advantages of the alternatives.

The calculation of the cost to users of prohibiting mercury barometers is complicated by the fact that the price of mercury barometers is not only determined by the technical properties of the barometers but also by the design. In addition the electronic barometers have some extra features. Despite the lower price of some types of mercury barometers compared to alternatives, there seems to be relatively little demand for mercury barometers.

It is therefore concluded that the prohibition of mercury barometers for professional use would not have any significant cost impact on users.

- General ban on the export of liquid mercury in measuring devices
A general ban on the export of mercury in measuring devices would have some impact on manufacturers of mercury measuring equipment in the EU. It is estimated that 30-50 employees in small and medium-sized companies are employed in the manufacturing of mercury sphygmomanometers for export outside the EU; 170-250 employees involved in mercury thermometer exports; and 2-20 employees involved in barometer exports. Just as European brands are requested by some customers because they are considered more reliable, a general export ban on mercury devices may also increase the demand for alternatives produced in Europe, having a positive impact on EU manufacturers of alternatives. However, the increased demand for alternatives would probably not fully outweigh the reduced demand for mercury devices.

Options for reducing mercury input from catalysts in polyurethane elastomers
In total 20-35 tonnes mercury in catalysts end up in polyurethane (PU) elastomers on the EU market every year. Mercury catalysts are today used in approximately 5% of the PU elastomer systems. Alternatives exist to virtually all applications, but the identification of appropriate formulations would, in many PU elastomer systems, require some research and development effort. The assessment of policy options in this study analysed the impacts of a “fast” or a “slow” phase-out of the use of mercury in PU elastomer systems.

Based on the analysis, it is concluded that the policy option proposing a phase-out of the use of mercury in polyurethane elastomers over a 3-5 year period (slow phase out), would appear to be preferable to other options, with overall positive impacts on the economy and society. Further refinements to this policy option should be considered, such as requiring before 3 years a request for exemption from any stakeholder who cannot comply with a 3-year phase-out, and a complete ban after 5 years with no further exemptions.

It should be kept in mind, as in the case of other mercury-containing products, that aerospace, marine and military applications of PU elastomers may claim exemptions for reasons of safety, reliability, security, etc. This research suggests that all such users of PU elastomer applications – if they take the phase-out period seriously – should be able to identify mercury-free alternatives within a three- to five-year time frame. Moreover, the typical supplier of PU elastomer systems will not be interested in stocking a mercury-catalysed product for a relatively small and declining market.

It should be emphasised that the global impact of a phase-out of mercury in PU elastomers will be significant. On the one hand, other countries have shown a general willingness to follow the EU lead toward better mercury management and environmental responsibility. On the other hand, industry has little interest in selling a different product within the EU from that marketed outside the EU – a practice that is not only commercially inefficient, but also leaves industry open to criticism of applying different standards to different markets.

It is estimated that the cost of phasing out the use of mercury in PU elastomer systems, if all costs of research and development of alternative systems are included, would be in the range of €40-100 per kg mercury substituted.

Options for reducing mercury input related to mercury porosimetry
This study has emphasised that the mercury consumption for porosimetry is substantially larger than previously expected; in fact this use may be among the largest remaining uses in the EU today. The mercury usage takes place in laboratory conditions, which tend to ensure a certain containment of the mercury. Direct releases to the environment are however expected, and due to the substantial amounts of mercury involved, the generated mercury-containing waste contributes significantly to the mercury input to waste in the EU. These preliminary findings indicate that it might be useful to investigate this mercury usage in more detail in future work and that regulation may be warranted in the longer perspective.

Two alternatives to mercury porosimetry are commercially available today. They currently have some limitations as regards measurable materials and pore sizes, and investment costs should be foreseen for a possible development of alternatives covering all situations. Unless mercury use for porosimetry is regulated, it is likely that the further development and implementation of alternatives will be slow. The measurement of pore characteristics is based on analysis standards, and establishment and a wide use and acknowledgement of new standards usually take time. Also, the alternative methods do not measure exactly the same characteristics as the mercury porosimeter, and therefore a change in methods will require the users' research on comparability between the methods.

Until comprehensive alternatives exist, an exemption to a ban on the sale of new mercury porosimeters would be necessary for (at least) the measurement of hydrophilic samples for which pore sizes outside the range 0.06 µm - 1000 µm are important for documentable technical reasons. Except for industries' quality control of a very specific range of materials, many users would in effect be covered by such an exception

Policy options for other applications
Among other applications, the cases of improved management of mercury in lighthouses, and restricting the use of mercury in biocides have been highlighted in this study. Policy options for these applications have not been analysed in detail, but it has been considered whether some policy options are immediately obvious. It is proposed to consider including mercury from decommissioned lighthouses in the new Regulation (originally tabled as COM(2006)0636) on the banning of exports and the safe storage of metallic mercury. With regard to the use of mercury compounds as biocides, the analysis shows that this application will virtually end within the next two years, as none of the relevant mercury compounds have been notified or included in the review programme. For this reason no policy measures have been proposed for this application.

Comparison of policy options
As this study’s assessment of some impacts of policy options, especially the benefits of different policies, is largely qualitative, it is not feasible to perform a comprehensive comparison of the different policy options. Based on the various costs calculated, however, it is possible to roughly prioritise the policy options on the basis of cost-effectiveness – specifically in terms of cost to the end-user per kg reduction in mercury input to society.

In spite of the broad range of uncertainties in some calculations, the analysis clearly indicates that the costs of substituting one kg of mercury in sphygmomanometers, barometers and PU elastomers are very small compared to the costs of substituting one kg of mercury in dental amalgam or thermometers (Table 0-4).

For both mercury sphygmomanometers and PU elastomers, the quantities of mercury that could be eliminated by these policy options are very significant as compared to the total mercury consumption in the EU. Furthermore, the assessment demonstrates that the impact on EU manufacturers of a restriction of mercury use for these two applications would be very small, and on balance, the overall impact would be positive.

A ban on the marketing of mercury-containing PU elastomers would also have a very significant impact on the total amounts of mercury directed to general waste, as these elastomer products today are neither separated for recycling nor disposed of as hazardous waste.

Table 0-4 Overview of the main costs to end-users per kg reduction in mercury input resulting from different policy options

<table>
<tr><th>Product group</th><th>Policy option</th><th>Potential for reducing mercury input
(t Hg per year)</th><th>Cost to the end-user of reduced mercury input
(€/ kg Hg)</th><th>Main constraints</th></tr>
<tr><td>Dental amalgam fillings</td><td>General ban on mercury in dental fillings</td><td>80 - 110</td><td>11,000 - 78,000</td><td>Price and some drawbacks of alternatives</td></tr>
<tr><td>Sphygmomanometers</td><td rowspan="3">Extend the ban on marketing of liquid mercury in measuring devices in 76/769/EEC</td><td>3 - 7</td><td>(-26) - 99</td><td>Lack of clear statements from the medical authorities regarding reliability of alternatives</td></tr>
<tr><td>Thermometers</td><td>0.2 - 0.6</td><td>5,000 - 20,000</td><td>Price of alternatives; use of mercury thermometers as analytical standards</td></tr>
<tr><td>Barometers</td><td>0.1 - 0.5</td><td>~0</td><td>Tradition</td></tr>
<tr><td>PU elastomers</td><td>Ban on marketing of mercury catalysts in PU elastomers</td><td>20 - 35</td><td>40 - 100</td><td>Time needed for customised development of mercury-free systems</td></tr>
<tr><td>Porosimetry</td><td>Ban on the marketing of mercury porosimeters</td><td>10-100
(long term)</td><td>not yet quantified</td><td>Alternatives are not available for all applications</td></tr>
</table>

Conclusion

Overall, therefore, of the applications for which impacts have been analysed more closely, there is a sound basis for concluding that dental amalgam and thermometers should be seriously considered for further restrictions, while measures to reduce the mercury input due to sphygmomanometers, barometers and PU elastomers may be put forward as soon as possible without major impacts on manufacturers and users.

With respect to dental amalgams, obligatory installation of high efficiency filters in dental clinics is a very cost-effective measure for reducing mercury releases to the waste water systems and may be put forward as soon as possible.

1 Introduction

1.1 Background and objectives

Mercury release reductions are not by any means a new focus in the European Union context; they have been pursued through individual community initiatives for more than two decades, targeting atmospheric mercury emissions, mercury-containing wastes and consumer safety, among other issues.

A new perspective, however, is evident in the concerted actions embodied in the Community Strategy Concerning Mercury, which gives an overview of the remaining issues to be addressed in order to construct and maintain an overarching and integrated community-wide framework to properly manage mercury and adequately control its adverse environmental impacts.

The Community Strategy Concerning Mercury has a strong potential to influence mercury reductions not only within the territory of the European Union, but truly globally. In its position as one of the strongest economic powers of the world - a power with a focus on future sustainability - the European Union has a large role to play in encouraging responsible global management of mercury pollution. Apart from the direct regional environmental benefits of reduced mercury use, the increased global cooperation on managing mercury pollution, largely spurred by the encouragement of the European Union, makes it that much more important to signal that Europe makes substantial and systematic efforts to manage mercury within, as well as beyond, its own territory.

The Community Strategy Concerning Mercury deals with all aspects of mercury releases to the environment, including both releases due to mercury impurities in raw materials and fossil fuel resources, and releases due to intentional mercury use in products and processes.

This study pertains mainly to the internal EU aspects of mercury management, yet with links to the global situation, and mainly to the flows and releases of mercury associated with its intentional use in products and processes.

The study provides a background for a number of actions described in the Community Strategy Concerning Mercury:

- Action 4. The Commission will review in 2005 Member States' implementation of Community requirements on the treatment of dental amalgam waste, and will take appropriate steps thereafter to ensure correct application.

- Action 7. The Commission intends to propose in 2005 an amendment to Directive 76/769/EEC13 to restrict the marketing for consumer use and healthcare of nonelectrical or electronic measuring and control equipment containing mercury.

- Action 8. The Commission will further study in the short term the few remaining products and applications in the EU that use small amounts of mercury. In the medium to longer term, any remaining uses may be subject to authorisation and consideration of substitution under the proposed REACH Regulation14, once adopted.

- Action 10. The Commission will undertake further study in the short to medium term of the fate of mercury in products already circulating in society.

Objectives
The objectives of this study are as stated in the Technical Description of the invitation to tender:

"*The aim is identifying the possibilities for further reducing mercury use in products and applications and for reducing the amounts of mercury already in society.*

The expected results of the study are to get an overview on the situation in the EU-27 + Norway and Switzerland and to consider whether further actions/legislation on the EU level are appropriate for:

- *Mercury use in products and applications;*
- *Mercury in existing products and other uses already circulating in society.*"

1.2 Methodology

Questionnaire and stakeholder consultation responses
Data have been collected from the EU Member States + Norway and Switzerland by use of a questionnaire sent to the national environmental authorities (see Annex 7). The questionnaire included questions on mercury use, waste collection and treatment, mercury stocks and contaminated sites in these countries. Answers have been received from 20 Member States + Norway and Switzerland.

The obtained information has been supplemented with data submitted by some Member States as part of the European Commission's stakeholder consultations and other preparatory work undertaken for the preparation of the recent proposals for regulation with regard to: 1) the mercury export ban/safe storage, and 2) certain mercury-containing measuring devices (of which most are available from DG ENV's mercury website at http://ec.europa.eu/environment/chemicals/mercury/index.htm).

Statistical data
Statistical data on current and historical import, export and production of relevant products and materials have been collected from the Comext and Prodcom databases on Eurostat's website. Data on export of mercury chemicals have been obtained from the PIC notifications submitted to the secretariat of the Rotterdam Convention, and data on transboundary transports of mercury waste have been obtained from the Basel Convention Secretariat.

Contact to market actors
The overview of current use of mercury in products and processes have mainly been obtained from market actors. For four of the application areas, chlor alkali, batteries, light sources and dental amalgam contact has been established to the European trade organisations, and the quantitative estimates is to a large extent based on data from statistics and trade organisation. For the other application areas contact has been established to manufacturers and major suppliers. Manufacturers has been identified by the questionnaire to the Member States, earlier stakeholder consultations and by internet search. Most of the identified manufacturers have been contacted by e-mail and/or telephone for obtaining information on applications, consumption and production figures and the availability of alternatives. Direct meetings has been held with manufacturers of sphygmomanometer, thermometers, barometers and polyurethane elastomers. Further recycling companies have been contacted in order to obtain an overview of the recycling paths and mercury quantities recycled. When using the information in the report, direct quotations to information sources are provided for some of the information whereas for other information the information source is kept confidential on request from the source. Contacted companies and organisations are listed in Annex 2.

Literature and internet search
Possible uses of mercury described in the literature have been assessed by the use of *internet*

search engines in order to clarify to what extent applications take place today in the world or the EU, and the applications have been briefly described. For a number of applications, actual use has been identified only outside the EU, but for those applications it cannot be ruled out that mercury-containing products in limited quantities may reach the EU market.

Representation of consumption figures
Mercury consumption figures are in the report indicated with ranges representing a 90% likelihood interval, which means that the actual figures for 10% of the estimates may be outside the indicated range. Production, import, export and waste quantities are represented by best estimates only. The indicated uncertainties in the consumption figures for each application area are representative of the uncertainties that apply to the other figures.

2 Mercury and alternatives in products and processes and accumulation in society

2.1 Chlor alkali production

The chlor-alkali industry is a major player in the European chemical industry. In 2006 it produced over 10.5 million tonnes of chlorine and 11.5 million tonnes of caustic soda in Europe, with a market value of over 7 billion (i.e., thousand million) euro.

Figure 2-1 Chlor-alkali production in the EU27+2 using the mercury cell process (2006)

Source: Euro Chlor Industry Review 2006-7 (2007)

2.1.1 Regulation of mercury cell plants

Historically important in Europe, mercury cell chlor-alkali plants use mercury in a highly energy-intensive electrolytic process that is more than 100 years old, in which mercury acts as a cathode for the massive electrical current applied, as well as an amalgamator of the sodium ions separated from a brine solution by the electrical current. While many of the plants in Europe (and elsewhere) have already been converted to mercury-free alternatives, about 45 of these facilities remained in operation in the EU in 2006, responsible for around 5.5 million tonnes of chlorine and about 6 million tonnes of caustic production (see Annex 4). Encouraged by the flexibility of the IPPC Directive, and aware that most chlor-alkali facilities will have become uneconomic or reached the end of their technical lifetimes by 2020 (SRIC 1998), the industry has volunteered to phase out most mercury-cell plants in the EU by 2020. This will occur through the closing of some plants and the conversion of others to the membrane process, in some cases expanding production capacity at the same time.

It is not yet clear how many plants may consider they should be excluded from the 2020 phase-out, nor is it clear on what basis such a determination might be made. The EU plants that produce potassium hydroxide, for example, representing about 1 million tonnes of annual chlorine capacity, may argue for continued use of mercury after 2020, although viable mercury-free alternatives are in use elsewhere in the world. The BREF Chlor-Alkali (2001) mentioned that some plants in Japan, which largely phased out the industrial use of mercury following the Minamata incident, were permitted to continue to use mercury cells to produce potassium hydroxide for many years after other uses were discontinued. Even in this case, however, the remaining Japanese plants had all been converted to mercury-free processes by 2002 (personal communication with Euro Chlor).

The quantity of mercury held by the electrolytic cells at any one time is estimated by industry to average about 1.8 tonnes per 1000 tonnes chlorine capacity, which would give about 10 thousand tonnes of mercury in the cell inventories for all of the EU plants. Depending upon one's assumptions about the phase-out, most of this mercury would no longer be needed by industry and would gradually be sent to Almadén, from where it may be legally exported until the EU export ban takes effect in 2011.

2.1.2 Mercury emissions, consumption and releases

The EU chlor-alkali industry is grouped in the industry association Euro Chlor (part of the chemical industry federation Cefic), which counts 95% of EU chlor-alkali production capacity among its members. According to industry reports, in the production of chlorine and caustic between 2002 and 2005, the Euro Chlor member companies consumed, on average, 173 tonnes (range 160-190 tonnes) of mercury every year in mercury cell chlor-alkali plants. In line with mercury balances prepared by industry, "consumption" refers to all mercury that is required to be added to the electrolytic cells. This mercury may come from purchases outside the industry, it may come from intra-industry transfers of mercury stocks, it may come from chlor-alkali industry wastes recycled off-site, or it may come from chlor-alkali industry wastes recycled on-site. Therefore, on average during 2002-2005, of the total 173 tonnes annually added to the electrolytic process, 30-40 tonnes of that came from off-site and on-site recycling operations. It is estimated that presently about half of the recycled mercury is recovered on-site, although five years ago the percentage was significantly lower.

These companies reported emissions and releases (mostly to the atmosphere, but also to water and to the chemical end-products) of 6-8 tonnes of mercury. They estimated the mercury disposed of in wastes at some 80-100 tonnes per year (after accounting for the 30-40 tonnes that were recycled). Using a mercury-in vs. mercury-out "accounting" system, industry reported another 41 tonnes (annual average for 2002 to 2005) of mercury releases or losses that were unaccounted for, referred to by industry as "difference-to-balance." These numbers are summarised in the table below for the EU and Switzerland. Norway no longer has any operating mercury cell plants.

Table 2-1 Mercury consumption in chlor-alkali plants in the EU and Switzerland based on Euro Chlor reports

	Tonnes mercury					
	2002	2003	2004	2005	Average 2002-5	2006 (est.)
Reported emissions to products, air and water	8	8	6	6	7	6
Reported mercury disposed of in waste	102	108	86	86	96	84
Reported unaccounted for ("difference-to-balance") mercury losses	12	20	78	53	41	45
Total mercury losses and disposal (may not be exact due to rounding)	122	135	171	146	144	135
Estimated mercury recovered from waste	25	25	30	35	29	35
Total industry mercury consumption	147	160	201	181	173	170

2.1.3 Accumulation in society

Cell inventory and other easily recoverable mercury

The mercury "accumulation in society" related to mercury use in the production of chlor-alkali is dominated by the "inventory" of mercury in the electrolytic cells.

The knowledge derived from various decommissioning experiences was first summarised in the Euro Chlor guidebook, "Decommissioning of Mercury Chlor-Alkali Plants, Env. Prot. 3, 1999," which outlined a responsible general approach to decommissioning, demolition and site remediation. As noted by Euro Chlor, there are a variety of other locations where mercury may be found when a plant is decommissioned, including:

1. Hg accumulated in equipment other than cells (tanks, pits, catch-pots, traps, etc.) from which Hg can be drained or recovered periodically, or in some cases (headers, stock-tanks, etc.) only during plant shutdown;

2. Hg accumulated in the plant as wastes, such as in sludges, sewers, Hg sumps, etc.;

3. Hg wastes (perhaps temporarily, perhaps indefinitely) stored on site, including solid wastes, sludges, settling ponds, etc., including formerly acceptable forms of waste disposal;

4. Hg inadvertently accumulated on site, such as in steelwork and building materials, especially in the cell room;

5. Hg penetrated into the subsoil through tank leaks, a permeable cell room floor, or the drainage system.

In a detailed review of several decommissioning projects, it was concluded that the amount of mercury that may be recovered from a chlor-alkali site relatively easily, varies from 1.6 to 2.7 tonnes of Hg per 1000 tonnes of chlorine production capacity, with close to 85% of that originating in the cell room (Table 2-2).

Table 2-2 Examples of mercury recovered and disposed of at decommissioning (Verberne and Maxson 2000)

MCCA site decom-missioned (Annual production capacity)	Company	Raw Hg col-lected (t Hg/1000 t Cl_2 prod. capacity)	Other Hg recovered (t Hg/1000 t Cl_2 prod. capacity)	Total Hg liberated (t Hg/1000 t Cl_2 prod. capacity)	Hg disposed in waste (t Hg/1000 t Cl_2 prod. capacity)
Roermond, Netherlands (146,000 t Cl_2)	Solvay	1.5	0.11	1.65	0.08
Delfzijl, Netherlands (48,000 t Cl_2)	Akzo Nobel	1.3	0.28	1.58	0.29
Cornwall, Ontario Canada (50,000 t Cl_2)	ICI Canada	2.1	negligible	2.2	0.25
Skoghall, Sweden (80,000 t Cl_2)	Akzo Nobel	2.4	0.15	2.59	0.13
Bohus, Sweden (6,000 t Cl_2)	Akzo Nobel	1.5	1.20	2.70	N/a
Typical values		1.3 - 2.4	0.1 – 1.20	1.6 - 2.7	0.1 – 0.3

Warehousing
Besides mercury in cells, there is also a main storage room at each site where mercury is stored so as to be available as needed to top up the cells when the mercury level decreases too much due to various losses and releases, including mercury wastes. It is estimated that the mercury warehoused is equivalent to about one year’s consumption, i.e., probably on the order of 200 tonnes.

Products
There is also trace mercury released in the chemical products, in this case mostly the caustic soda. Industry reported in 2005 losses of mercury to products of 0.01-0.68 g Hg/tonne of chlorine capacity, with an average of around 0.1 g Hg. If one assumes that most of this 0.1 ppm Hg goes to the caustic product, and that 6 million tonnes of caustic are produced annually, that is equivalent to an estimated 600 kg Hg content in the caustic marketed each year. In most cases that level of contamination meets customer requirements for product quality and the mercury goes with the caustic into the product supply chain.

2.1.4 Mercury-free alternatives

There are two primary mercury-free processes for producing chlorine and caustic – membrane and diaphragm – that have long been available, are less costly, are more energy-efficient and are less damaging to the environment, as reported by the EIPPCB report on best available techniques in the industry (BREF Chlor-Alkali 2001). The United States, which has only 5 mercury cell plants remaining in operation, initially relied mostly on the diaphragm process as an alternative to mercury cells because asbestos and brine were more accessible on the North American continent. The membrane technology was not demonstrated in a full-scale plant until 1983. However, since the early 1990s virtually all conversions and new plants are using this process –

both for the production of caustic soda (NaOH) as well as the production of caustic potash (KOH).

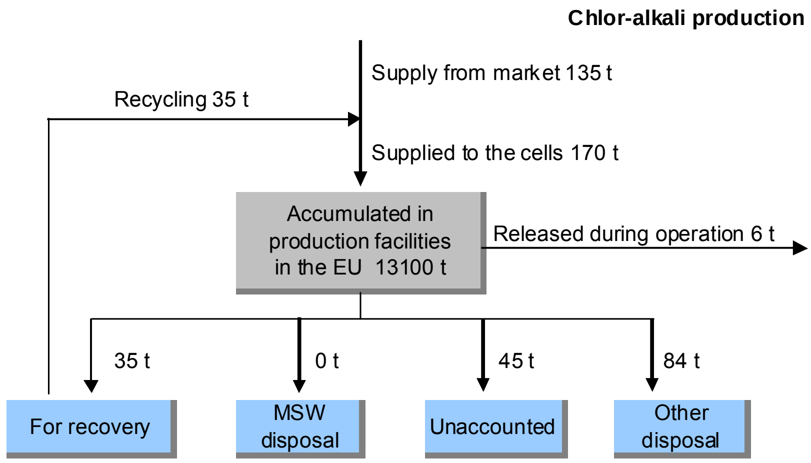
2.1.5 Wastes and releases

As mentioned above, most of the 6-8 tonnes reported Hg emissions are atmospheric, although just under one tonne of that is emitted to surface waters. Some 80-90 tonnes of mercury wastes go to final disposal and another 30-40 tonnes of wastes are recycled both on-site and off-site.

However, there is ongoing debate as to what happens to the 40 or more tonnes of mercury referred to by industry as “difference-to-balance”. Industry has offered explanations of these losses as annual variations in mercury inventories, uncertainties in measuring techniques or estimates of mercury in waste, accumulations of mercury in piping and equipment, etc. All of these explanations contain some elements of fact, but none has come close to technically justifying the large quantities of mercury that cannot be accounted for. A recent analysis drew on several peer-reviewed research papers to make the case that the atmospheric mercury emissions of most chlor-alkali plants are routinely underreported – not intentionally, but rather due to the complexity and design of the processes, equipment and structures that render any comprehensive measurement of mercury emissions virtually impossible (EEB 2006). As a compromise position, one might allocate these unexplained mercury losses among waste disposal, fugitive emissions to the atmosphere, etc., but at present there appears to be no political consensus either for such a compromise, or for continuing to completely ignore these losses.

2.1.6 Mercury mass balance

The obtained data on the flows of mercury for chlor-alkali production are summarised in the flowchart below.



2.2 Light sources

2.2.1 Major applications of light sources with mercury

Mercury lamps are efficient light sources, typically consuming 3-5 times less energy than incandescent (filament) lamps of comparable light output. Further, their useful life is typically 5-10 times the average 1000 hours lifetime of incandescent lamps (ELC 2004).

A typical mercury lamp consists of a phosphor coated glass tube with electrodes at both ends. The tube is filled with mercury vapour that is excited to a higher electronic state when electricity is passed through the lamp. As the mercury is energized it emits ultraviolet radiation (UV), which is absorbed by the phosphor-coated glass, causing it to fluoresce and emit visible light (Kuiken 2002). According to the Illuminating Engineering Society of North America, it would be possible to produce a fluorescent lamp without mercury, but the lamp would be some 70% less efficient (Lightfair 2002).

Mercury-containing lamps include primarily fluorescent lamps (tubes and compact fluorescent lamps (CFLs)), high-intensity discharge (HID) lamps (mercury vapour, metal halide, (most) high-pressure sodium, low-pressure mercury discharge, etc.), and cold cathode (ultraviolet and (some) “neon”) light sources.

Fluorescent lamps include, among others, straight tubes of varying lengths, compact fluorescent lamps used to replace incandescent light bulbs, halo-shaped indoor lamps, and small fluorescent (dimmable cold cathode) lamps found in backlit LCDs in laptop computers and other devices, appliances, navigational systems, etc. They are typically used in indoor office lighting and most other commercial applications, while CFLs are increasingly used in households. There are about 5,000 different fluorescent lamp products on the market. The straight tube lamp is the highest volume fluorescent lamp sold, accounting for approximately 70 percent of the market for fluorescent lamps used for general lighting purposes.

High-intensity discharge (HID) lamps, which commonly use mercury as a starting aid and for voltage control, are typically used in security lighting, street lighting, outdoor and parking lot lighting, warehouses and other “high-bay” structures, etc. High-pressure sodium lamps are used for high-intensity lighting, e.g., in commercial establishments and street lighting. Low-pressure sodium lamps, increasingly used in street lighting as well, are generally mercury-free. Low-pressure mercury discharge lamps, on the other hand, contain mercury to ensure efficient operation of the electric gas discharge.

Ultraviolet and other cold cathode lamps (preferred because they can be dimmed) are typically used in skin tanning equipment, laboratory and medical applications, while neon lamps are often found in theatrical productions, lighted signs, and a range of special purpose applications.

For simplicity one may focus on the three major types of lamp in terms of overall sales and mercury content – fluorescent tubes, CFLs (both integral and non-integral) and HID lamps.

2.2.2 Lamp supplies and mercury content

The European Lamp Companies Federation, ELC has said it does not have good information on EU lamp imports and exports. The following table provides an overview of the evolution of EU trade with third countries in various mercury lamps. In nearly all lamp categories, EU imports have increased by 2-3 times over a 6-year period. Only in the category of metal halide lamps have EU exports increased as much.

Table 2-3 EU import/export of mercury lamps (COMEXT database) - tonnes

COMEXT code & lamp types		2000	2003	2006
8539 31 10 –(tubes) DISCHARGE LAMPS, FLUORESCENT, HOT CATHODE, WITH DOUBLE ENDED CAP	EU27_extra import EU27_extra export	3,482 22,441	3,081 20,548	7,175 26,759
8539 31 90 – (CFLs) DISCHARGE LAMPS, FLUORESCENT, HOT CATHODE (EXCL. WITH DOUBLE ENDED CAP	EU27_extra import EU27_extra export	6,680 6,181	9,201 5,920	22,200 4,945
8539 32 10 – (HID-1) MERCURY VAPOUR LAMPS	EU27_extra import EU27_extra export	594 1,030	393 838	1,065 317
8539 32 50 – (HID-2) SODIUM VAPOUR LAMPS	EU27_extra import EU27_extra export	130 924	349 773	481 567
8539 32 90 – (HID-3) METAL HALIDE LAMPS	EU27_extra import EU27_extra export	372 516	773 513	1,029 1,392
8539 39 00 – (other) DISCHARGE LAMPS (EXCL. FLOURESCENT, HOT CATHODE LAMPS, ULTRAVIOLET LAMPS, ETC.)	EU27_extra import EU27_extra export	1,349 1,036	2,562 1,728	2,062 802

Source: COMEXT database

Mercury content of domestic and commercial lamps

The following table gives some ranges of the mercury content of various lamp types.

Table 2-4 Historic mercury content of common lamp types

Lamp type	Mercury content of lamp (mg Hg/item)	Country/-region for data	Source, remarks
Fluorescent (double end)	30-40 (1993) 15 (1997) 10 (2002)	European Union	(Floyd *et al.* 2002)
	10-22	USA	(NJ MTF 2002)
	23-46	Canada	(Environment Canada, 2003)
	3-4	Global	Lowest content on the market
Compact fluo-rescent (CFL, single end)	5 (1997) 5 (2002??)	European Union	(Floyd *et al.* 2002)
	10	Canada	(Environment Canada 2003)
High pressure mercury vapour	75 (1993) 39 (1997) 30 (2002)	European Union	(Floyd *et al.* 2002)
High-pressure sodium	20 (1993) 25 (1997) 30 (2002)	European Union	(Floyd *et al.* 2002)
Metal halide	60 (1993) 30 (1997) 25 (2002)	European Union	(Floyd *et al.* 2002)

According to ELC information, a fluorescent tube may now be produced with less than 10 mg mercury, a CFL may have less than 5 mg, and HID lamps still have up to 30 mg on average. The mercury content for lamps representing best available technology decreased from about 30 mg/lamp in 1994 to about 8 mg/lamp in 2000 (ELC 2008b). One research effort calculated that the average mercury content of all lamps produced in the EU in 1997 was 11.3 mg per piece (Floyd *et al.* 2002).

ELC has stated that in 2006 the "*approximate volume of Hg containing lamps sold on the EU market (EU 27 and EFTA countries) by ELC Member Companies result[ed] in approximately 5 tonnes of Hg*." No details of the supporting calculation were provided, except that 50% of the total was allocated to fluorescent tubes, 25% to CFLs and 25% to HIDs. In addition, a large (and increasing) number of lamps, especially CFLs, are imported into the EU. Many of these lamps have no link to ELC member companies. Among their various lamp related activities, the ELC Member Companies also export Hg containing capsules/pills and discharge tubes to production locations outside of Europe.

Converting the volumes of lamps in Table 2-3 above to lamp units, and combining the import and export quantities of lamps with the production data from the PRODCOM database gives the EU consumption of different lamp types as below.

Table 2-5 EU market for mercury lamp types (Comext + PRODCOM data)

EU27 market for mercury-containing lamps (2006)		Units (million)	Hg content (g/unit)	Hg content (tonnes)	Estimated range (tonnes)
Fluorescent tubes	EU27_production	552	0.010	5.52	
	EU27_extra import	60	0.010	0.60	
	EU27_extra export	223	0.010	2.23	
	EU27_consumption	389	0.010	3.89	3.3-4.5
CFLs	EU27_production	255	0.005	1.28	
	EU27_extra import	247	0.005	1.23	
	EU27_extra export	55	0.005	0.27	
	EU27_consumption	447	0.005	2.23	1.9-2.6
HID lamps	EU27_production	39	0.030	1.18	
	EU27_extra import	15	0.030	0.44	
	EU27_extra export	12	0.030	0.35	
	EU27_consumption	42	0.030	1.27	1.1-1.5
Other lamps	EU27_production	81	0.025	2.03	
	EU27_extra import	29	0.025	0.72	
	EU27_extra export	35	0.025	0.88	
	EU27_consumption	75	0.025	1.86	1.6-2.1
TOTAL	EU27_production	928	0.011	10.01	
	EU27_extra import	350	0.009	2.99	
	EU27_extra export	325	0.012	3.74	
	EU27_consumption	953	0.010	9.26	7.9-10.7

The data in the above table concerning EU production and consumption of tube and CFL lamps are higher than most previous estimates. The average mercury content (in 2006) of about 10 mg per lamp for all lamps consumed in the EU is in the middle of the range of various estimates. It is quite consistent with the average mercury content (11.5 mg) estimated for the 668 million mercury lamps sold in the US in 2005 (Cain *et al.* 2007). Furthermore, the roughly 5 tonnes of mercury said by ELC to be put on the EU market by ELC member companies in 2007 supports the above estimate of mercury in EU production less exports. Finally, the 10 tonnes of mercury used by EU lamp manufacturers, not including their exports of mercury pills or capsules to manufacturing operations outside the EU, is supported by a mercury supplier's estimates of mercury shipped to lamp manufacturers. Considering various uncertainties in these numbers, the total mercury consumption within the EU is estimated at 8-11 tonnes in 2006, and the 2007 figures are estimated to be within this range as well.

New requirements under discussion for the EU Ecolabel, among other pressures, may be expected to push industry in the direction of longer-life lamps, lower mercury content, mandatory mercury labelling, and enhanced collection and recycling.

Mercury lamps used in electronics
In addition to the lamps described above, millions of energy-efficient lamps are also used in electronic devices, as summarised in the following table. While these lamps are typically small, for technical reasons they often contain nearly the quantity of mercury as do larger CFLs, and for some devices such as laptop or TV displays, there may be 6 or more lamps in one display. Based on a paper developed for the UK (AEA 2007), the quantity of mercury in these lamps put on the UK market in 2007 was estimated at about 400 kg, as in Table 2-6. Taking into account the different economic realities across the EU27+2, it was calculated that the UK accounts for about 13% of EU total GDP at purchasing power parity (PPP). This implies mercury consumption in these lamps for the EU27+2 of approximately 3.5-4.5 tonnes, most of it imported into the EU with the electronics.

Table 2-6 Mercury lamps in electronic devices (derived from AEA 2007)

Device	UK total demand 2007 (millions)	Mercury content product range (mg)	UK allocation demand 2007 (millions)	UK allocation mercury content 2007 (kg)
Multi-media monitor		75.0	0.2	15
LCD display monitor	10.5	2.5	2.5	6
		7.5	5.0	38
		30.0	2.3	69
LCD TV flat panel	3.0	2.5	0.5	1
		7.5	1.5	11
		30.0	1.0	30
Digital picture frame	0.5	2.5	0.5	1
LCD projector	0.1	75.0	0.1	8
Laptop/notebook	8.0	2.5	3.0	8
		30.0	5.0	150
Fax/copier/printer	2.5	2.5	1.0	3
		30.0	1.5	45
Fax	0.1	2.5	0.1	0
Scanner	0.5	2.5	0.2	1
		30.0	0.3	9
Copier	0.5	2.5	0.2	1
		7.5	0.3	2
Camcorder/camera	LEDs?	2.5	0.0	0
Audio equipment	LEDs?	2.5	0.0	0
DVD/VCR players	6.8	2.5	6.8	17
Telephones	LEDs?	2.5	0.0	0
TOTAL UK				414

2.2.3 Mercury accumulated in society

ELC has stated that when it made a calculation for 2006, it counted approximately 3.3 billion lamps that had been sold by its member companies installed in the EU27 and EFTA at that time. ELC has estimated that those lamps contain an inventory of some 25 tonnes of mercury, which implies an average mercury content per lamp of 7-8 mg. Due to the significant decline in the mercury content of fluorescent tubes and CFLs during the last 10 years, and little or no decline in the mercury content of HIDs, ELC has estimated that 60% of that Hg inventory is likely to be in fluorescent tubes, 25% in CFLs and about 15% in HID lamps.

In calculating the accumulation of mercury lamps and mercury in society, one should recall that there are significant imports to the EU other than those produced by ELC member companies. If one takes 5 years as the minimum average lifetime of a mercury-containing lamp, and assumes that the overall EU consumption of lamps has increased 1-4% per year, by the year 2006 one would have an accumulation of some 4.4 – 4.6 billion lamps installed, as calculated in Table 2-7.

Table 2-7 Status 2006 – Accumulation of lamps and mercury in the EU

	Lamps consumed assuming 1% mkt. growth (millions)	Lamps consumed assuming 2% mkt. growth (millions)	Lamps consumed assuming 3% mkt. growth (millions)	Lamps consumed assuming 4% mkt. growth (millions)	US average mercury content (mg)	EU27 average mercury content (mg)
2000					13.34	
2001	907	863	822	783		11.56
2002	916	880	847	815		11.19
2003	925	898	872	847		10.82
2004	934	916	898	881		10.46
2005	944	934	925	916	11.50	10.09
2006	953	953	953	953		9.72
Accumulated lamps 2002-2006	4,672	4,582	4,495	4,412		
Accumulated mercury 2002-2006	48.8	47.8	46.9	46.0		

With regard to the mercury content of these lamps, it is obvious that those lamps installed in 2002 had a higher average mercury content than those installed in 2006. The evolution of the EU mercury content is assumed to be in line with, although somewhat lower than, calculations made for the US market, where the average mercury content in 2000 was estimated at 13.34 mg, and declined to 11.5 mg by 2005. Following this reasoning, the accumulated mercury in lamps in use in the EU is likely in the range of 45-50 tonnes.

To this quantity should be added the accumulated mercury in lamps in electronic devices. Since these devices are kept typically for several years, and many are hoarded even after that, it seems reasonable to assume an accumulation of 4-5 years' sales, which would imply another 15-20 tonnes of mercury accumulated in society in these lamps.

2.2.4 EU producers of lamps

According to ELC, it is estimated that one-third of all lamps currently installed in the European Union are energy efficient, while two-thirds are energy inefficient incandescent, halogens, etc.

It is estimated that approximately 85% of lamps currently installed in EU homes are energy inefficient.

EU lamp manufacturers currently produce 8 times more "traditional" inefficient lamps than the more energy-efficient equivalents. In total, 10 lamp factories and 6 pre-material (e.g. glass, filament, etc.) factories currently produce incandescent lamps in Europe.

Table 2-8 ELC member companies manufacturing representing 95% of all EU production of mercury-containing lamps.

Country	Name of producer
NL	Philips Lighting, The Netherlands
DE	Aura - Aura Lighting Group; Germany
DE	BLV (Ushio Group - Japan)
HU	GE Consumer & Industrial Lighting (GE Lighting - USA)
BE, DE, UK	SLI Sylvania, Germany
DE	Narva - NARVA Lichtquellen GmbH + Co. KG, Germany
DE, CZ	Osram GmbH, Germany

2.2.5 Mercury-free alternatives

General domestic lighting

Over the last decades, no commercial and equally energy-efficient alternatives have been available for general consumer use (while many with higher energy demand), and technological front-runners' efforts have been concentrated on reducing the amount of Hg used per lamp. Thereby, mercury consumption in the best available lamps has been reduced to almost a tenth of the amounts used earlier in standard fluorescent lamps. Much of the global supply is however produced at low price with less focus on Hg reductions.

In recent years, several types of Hg-free low-energy lamps have been developed, light emitting diodes (LEDs), which are now commercially available and usable with standard round sockets and field emission lamps (Maag *et al.* 2007).

LEDs. Light emitting diodes have been available for decades, but in colours unfit for room lighting and similar uses. Just during the last five years or so, new types of diodes with colours closer to a "white" colour mix have become commercially available, and beginning in Northern Europe, these diode types have become available for general lighting purposes with standard sockets (authors' on-site observations; Jula (2007); Harald Nyborg (2007); Trenden; (2008); Dioder.dk (2008). LED lamps are now also available at the so-called "warm white" temperature rating (see e.g. Dioder.dk, 2008); the light quality of these lamps was not investigated for this study. By 2007, however, the emitted light spectra were still not close enough to the appreciated warm and wide spectrum emitted by traditional incandescent lamps (Maag *et al.* 2007). Technical development bridging this hurdle is fairly close to commercialization, for example by applying specialized diffuser materials, which mix and spread the light, in combination with optimized mixes of coloured LEDs. Developers predict a full commercialization within 10 years or less (Ingeniøren 2007).

LEDs for general lighting purposes using 230 and 110 volts directly, without any need for AC/DC transformers, have been developed recently. The power efficiency is, according to an importer, 60 lumens/watt, with improvements expected to double this value by the end of 2008 (Optoga 2007). The ability to function without a transformer could be important, as the present built-in transformer may in some cases be the weak point in LED lamps that limits the lifetime of the lamp. These LEDs are not yet available as standard units for sale to the public.

Nano-scale LEDs have been produced in labs at the University of Lund, Sweden, featuring lifetimes up to 100,000 hours (about double that of current commercially available LEDs), with half the energy consumption of straight fluorescent lamps, and with a power efficiency equivalent to normal consumer CFLs (Bergdroff 2007). LEDs can be used with dimmers (which standard CFLs cannot). By the end of 2007 nano-scale LEDs were under development for marketing.

Field emission lamps. Another technology potentially substituting for CFLs is field emission lamps which, however, currently appear to use more energy per lumen than compact fluorescent lamps (CFL). Advantages compared to CFLs, in addition to no content of Hg and lead, are instant lighting (no flickering), efficient function even at low temperatures (including below freezing) and they can be used with dimmers. A price comparable to that of CFLs is expected (Baltscheffsky 2007; NyTeknik 2007).

High-efficiency incandescents. Last year GE announced it would start selling a high-efficiency incandescent bulb in 2010 that would be nearly twice as efficient as existing incandescent bulbs (GE 2007). Ultimately, the company said, these new bulbs would be comparable in efficiency to compact fluorescents. Though major improvements have made them broadly acceptable, CFLs continue to have drawbacks for some consumers; for instance, their colour still isn't the same as incandescents (Deutsch 2008; Weise 2008). Thus, an incandescent bulb with the efficiency of a compact fluorescent could attract a sizeable market.

OLEDs. Organic light-emitting diode (OLED) lighting devices are under development. These devices are thin films made of polymers that create light when an electrical charge is applied. GE announced on March 11, 2008, that it had successfully demonstrated a manufacturing process for OLEDs that could dramatically lower their costs. Potential applications include electronics products such as flexible electronic paper displays, portable TV screens the size of posters, solar powered cells and high-efficiency lighting devices, according to the company, which said its goal is to introduce OLED lighting products by 2010 (GE 2008).

Low energy lighting is currently a high priority issue due to the pursuit of reductions of energy demand with a view to minimizing global climate change. The increased focus on energy saving lamps may perhaps enhance the development and marketing of Hg-free energy efficient lamps.

While HID mercury vapour lamps can generally be replaced by high-pressure sodium or metal halide lamps, both of the latter are now available in mercury free versions, including in most of the higher wattages.

Backlights for flat LCD screens

Traditionally lighted by small fluorescent lights, LCD flat screens are now available with LED backlights for high end computers, flat screen TVs and computer game stations. Infoworld (2006) has described their introduction on the market and stated that better performance and low energy usage were primary driving forces for their use, whereas a higher price had meant that LEDs had not yet in 2006 been spread to lower price products. Several aspects of high performance of LED backlights are described by producer Lumileds (2005), a Philips owned company headquartered in the US. By way of example, Sony has marketed several flat screen products with LED backlights (Sony 2008).

Automobile headlamps

The high-intensity effect of mercury lamps used as auto headlamps can be achieved or bettered by xenon headlamps without mercury.

The first use of LEDs in automobile headlights was introduced in 2004 (by high-end brand Audi). The automobiles' daytime running lights were LED based. Only in 2007, the first main headlamps (Japanese high-end brand Lexus) were LED based (Compoundsemiconductor.net, 2004, 2007).

Summary
An overview of marketed alternatives to mercury-containing light sources is shown in Table 2-9

Table 2-9 Overview of marketed alternatives to mercury-containing light sources

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury lamps	Substitution level	Remarks
Compact lamps, standard sockets	LED lamps, standard sockets	=	1	Available in consumer retail shops and internet shops in 2007 and 2008; price references: E.g. (Trenden 2008); (Dioder.dk 2008).
Backlights in PC laptop screens	LED backlights	+	1	(Sony 2008)
Backlights in LCD TV screens	LED backlights	+	1	(Sony 2008)
Backlights in computer game consol screens	LED backlights	=	2	Sony Playstation Portable (Infoworld 2006). Price of backlight is not deemed a determining factor for product choice.
Automobile headlights	LED headlights	=/+?	1	Price of headlight is not deemed a determining factor for product choice.

Key assigned to the overall current user/consumer price levels for mercury-free alternatives as compared to mercury technology:
– Lower price level (the alternative is cheaper)
= About the same price level
+ Higher price level
++ Significantly higher price levels (more than 5 times higher)
N Not enough data to assign an indicator

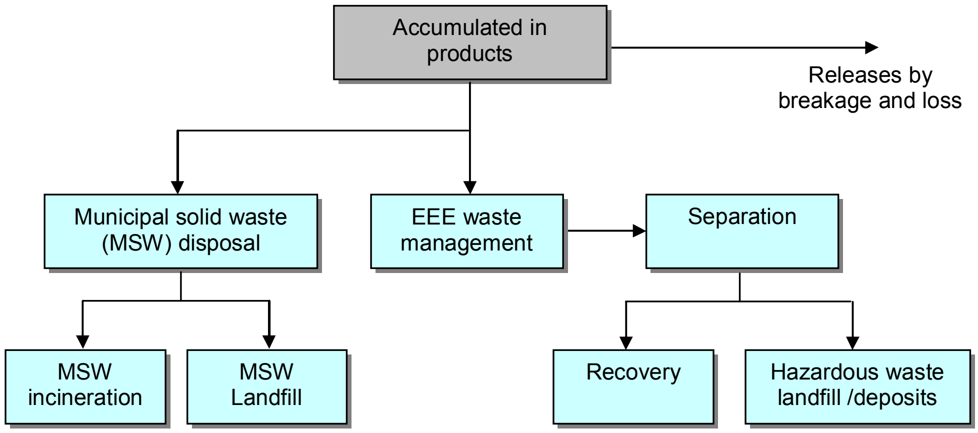
Key to assigned substitution level indices:
0 No substitution indicated in assessed data sources; development often underway
1 Alternatives are in commercial maturation, or are present on the market but with marginal market shares
2 Alternatives are commercially matured and have significant market shares, but do not dominate the market
3 Alternatives dominate the market, but new production with mercury also have significant market shares
4 Mercury use is fully, or almost fully, substituted
N Not enough data found to assign an indicator
? Indicator very uncertain due to limited data

2.2.6 Collection and treatment of mercury-containing light sources

The pathways of mercury from lamps in mercury-containing waste are shown in the diagram below.

With the implementation of the WEEE directive the manufacturers of lamps have taken over the responsibility of the collection and recycling of lamps. For WEEE from non-private households, from products falling under the definition of historical waste, the Directive requires that the financing of the costs of their waste management be provided for by producers, and Member States may alternatively provide that users other than private households be made partly or totally responsible for this financing. For the same products placed on the market after August

2005, the Directive simply states that producers will be responsible for financing their collection, treatment, recovery and environmentally sound disposal.



Obtained data for waste from mercury-containing lamps by Member States are shown in Table 2-10. The data represent the situation before implementation of the WEEE Directive, and the collection of lamps and the recycling of mercury from lamps may be higher today.

As the average mercury content of the lamps has decreased significantly over the years, the estimate of the total mercury content of collected lamps is highly dependent on the applied average concentration, and it is further difficult to compare data from different years. The mercury content of lamps representing best available technology decreased from about 30 mg/lamp in 1994 to about 8 mg/lamp in 2000 (ELC 2008b).

This may e.g. explain the large difference between the estimated mercury content of lamps collected in Germany and France, where the average content is estimated to be about 10 mg/lamp (best technology in 1998) in Germany and 42-63 mg/lamp (best technology about 1985) in France. The average mercury content of all lamps produced in the EU in 1997 was 11.3 mg/g (Floyd *et al.* 2002). The average content of waste lamps around 2003/4 was most probably 10-15 mg/lamp. The following Table 2-10 summarises information received from Member States concerning collection and treatment of waste lamps.

Table 2-10 Reported waste of mercury-containing lamps (based on questionnaire and stake-holder responses)

Country	Year	Tonnes waste	Number of lamps	Tonnes mercury	Treatment
DE	2003	7000-9000	35-45 million	0.35	The material is usually landfilled
DK	2001		3.1 million	0.05	2.6 million processed in Denmark, 0.5 million exported (Christensen *et al.* 2004)
FI	2000			0.23	About 50% recycled, remaining part landfilled
FR	2004		47 million	2-3	Processed by sorting glass, metals, mercury and powders
NL	2006	53			Separating mercury and recycling (esp. glass) (recovery)
NO	2006	355			
SE	2005	899			Exported for recycling in Denmark and Norway
CH	2007	450			Exported for recycling in France and Germany
BE, Flan	2004	1150			Recycling in Flanders
CY	2006	7			Recycling in Belgium
LV	2006	191			Recovered
PT	2002	150			54 t were exported for recovery
SL	2006	152			Reported that 152 t mercury were recovered, but it is here assumed that this is actually the weight of the recycled lamps
UK	2004		16 million		In 2004 about 100 million lamps were generated in the waste, of these 16 million were recycled

A recent assessment of the amount of WEEE collected and treated as a percentage of WEEE arising estimates that 28% of Category 5b waste (lighting equipment - lamps) was collected and treated in 2005 (Huisman *et al.* 2007). The lamps accounted for 1.7% of the total WEEE, corresponding to 28,000 tonnes, while the luminaires (Category 5a) accounted for 0.7%. The efficiency varies as shown in Table 2-11 from 0.00 kg/capita in the new Member States of Estonia, Hungary and Slovakia to 0.35 kg/capita in the UK. The high collection rate shown for the UK – compared to countries like Sweden and Belgium – is not in accordance with the data collected for the present study as shown in Table 2-10.

Table 2-11 Collection of WEEE Category 5 waste by country in 2005 in kg/capita (Huisman et al. 2007)

AU *	BE	CH	CZ	EE	FI	HU	IE	NL	SL	SE	UK	EU average
Inc 2	0.14	0.04	0.00	n.d.	0.03	0.00	0.07	0.06	0.00	0.11	0.35	0.08

* Included in other category

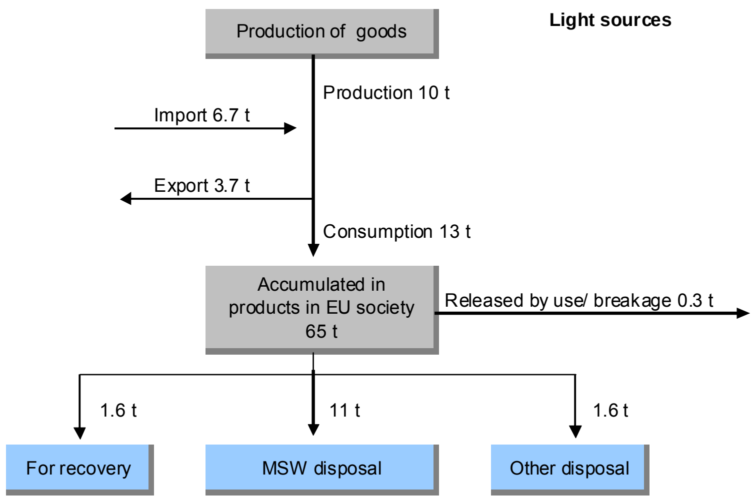
The data above represent the situation before a full implementation of the WEEE directive.

Many countries have today separate systems for collection of fluorescent lamps (Category 5 of the WEEE directive). This applies both to countries with a single National Compliance System and countries with Competing Collectives or National and Pan-European Consortia (Sander *et al.* 2007). Countries with systems specialised in collection of Category 5 waste are the Czech Republic (Ekolamp), Denmark (LWF), Ireland (ERP), Italy (Ecolamp, Ecolight, EcoR'It), France (Recyclum), Austria (UFH Lamps), Finland (FLIP Ry (Elker Oy)) and Slovakia (Eko-lamp) (Sander *et al.* 2007). The other countries have one or more companies that collect the Category 5 waste along with other waste categories.

The total number of collected lamps in France, Germany and the UK in 2003/4, representing about 40% of the EU27+2 population, was about 103 million lamps. The collected amounts in these countries are probably a little higher than the EU average, as these countries are among the countries with a better developed infrastructure for waste lamp management. On this basis the EU27+2 total collected lamps around 2004 is estimated at about 180-200 million lamps, and in 2006 at 200-220 million lamps. Assuming that lamps collected in 2006 were mostly installed in 2002, and that all 800-900 million lamps installed that year contained about 10 tonnes of mercury, one could calculate that the collected lamps contained 2.5-2.9 tonnes of mercury, plus another 0.5-1.0 tonne from lamps in collected electronics, for a total of 3.0-3.9 tonnes. There is not enough information in the tables above to derive a reasonable estimate of the number of these collected lamps in 2006 that were eventually recycled, but a rough estimate consistent with observations of previous researchers (Floyd *et al.* 2002) would be 40-60%.

2.2.7 Mercury mass balance

The obtained data on the EU flows of mercury consumed in lamps are summarised in the flow-chart below. It is roughly estimated that 2% of the mercury is released to the environment by breakage of the lamps. The output of mercury from society is smaller than the input reflecting the situation that the total mercury consumption has been increasing in spite of the lower mercury content per unit.



2.3 Batteries

2.3.1 Applications and battery types

Due largely to regulation, mercury is no longer added to standard primary batteries in normal commerce, although miniature, or button cell batteries, whose volume of sales continues to increase, remain under scrutiny due to their mercury content. The aim of Council Directive 91/157/EEC of 18 March 1991 on batteries and accumulators containing certain dangerous substances is the collection, safe recovery and disposal of spent batteries and accumulators containing dangerous substances (mercury, cadmium or lead). The adaptation referred to in Directive 98/101/EC prohibits the marketing of batteries and accumulators containing more than 0.0005% of mercury by weight. Button cells with a mercury content of no more than 2% by weight remain exempted, as do batteries for "medical equipment" and for "emergency and alarm systems."[1] It would appear that the latter clause would exempt many or most military uses of mercury batteries.

This research has confirmed that batteries remain an important concern with regard to mercury: 1) because of the large volumes marketed, 2) because older batteries appearing in the waste stream contain much higher quantities of mercury than new batteries, and 3) because there is persistent statistical evidence that mercuric oxide batteries (and/or battery parts), which are banned from commercial marketing and use due to their high mercury content, may continue to be traded through the EU.

Button cells
The following button cell batteries are now commonly marketed in the EU:

- Lithium manganese dioxide (0% Hg) - Typical applications: photographic devices, auto garage door openers, electronics;
- Silver oxide (0.2-1.0% Hg) - Typical applications: watches;
- Alkaline manganese dioxide (0.1-0.9% Hg) - Typical applications: calculators, small electronic devices, remote controls;
- Zinc air (0.3-2.0% Hg) – Typical applications: hearing aids, pagers.

Cylindrical or rectangular batteries
The following larger consumer batteries are now commonly marketed in the EU:

- Alkaline manganese (previously contained an average of 0.5% mercury to control the zinc reaction, then 25 mg Hg, and now 0.0005% Hg) - Typical applications: flashlights/torches, smoke detectors, consumer electronics such as cameras, radios, remote controls, toys, game consoles, etc.;
- Zinc carbon (previously used Hg as well, now Hg-free) – Typically for slow-drain applications like clocks, garage door openers, pagers, door bells, smoke detectors, etc.. These batteries tend to have a shorter life span than alkaline batteries;
- Lithium manganese dioxide (0% Hg) - Typical applications: Cameras, toys.

In addition, mercuric oxide, also known as zinc mercury (generally estimated at 30-40% Hg content) batteries were previously specified in medical and military equipment, where the long battery shelf life and the reliable and constant rate of discharge make these batteries especially

[1] In contrast, US law allows batteries with high mercury content to be sold for any use, but only if the manufacturer has established a system to collect the waste batteries and ensure that the mercury is properly "managed."

attractive. These batteries are still used, although no longer manufactured, in the EU. Therefore, the supply chain has become less transparent, and the quantities have been difficult to assess.

2.3.2 Battery markets and quantities of mercury

Consumer batteries

About 160,000 tonnes of portable batteries were sold in the EU15 in 2002, i.e., an average of 0.41 kg/capita (Bio Intelligence Service 2003), compared to about 0.58 kg/capita reported in France. The European Primary Battery Association (EPBA) has reported for 2003 partial EU15 market sales of 50,200 tonnes of zinc carbon primary batteries, 99,140 tonnes of alkaline primary batteries, and 610.8 tonnes of button cells (EPBA 2008), based on reports from Cegasa, Duracell, Energizer, Germanos, GP Batteries, Kodak, Leclanché, Mitsubishi, Moltech, Panasonic, Rayovac, Renata, Saft, Sanyo, Varta Consumer, and Varta Microbattery. For the EU27+2 the quantity of primary batteries marketed annually may be estimated at around 190,000 tonnes, based on European Battery Recyclers' Association (EBRA) data (Beaurepaire 2006). In line with the breakdown above, this would comprise 60-68 thousand tonnes of zinc carbon primary batteries, 120-132 thousand tonnes of alkaline primary batteries, and 700-750 tonnes of button cells.

According to EPBA, as the mercury content of button cells continues to decrease, state-of-the-art button cells (averaging 2.5-3.0 grams in weight) now contain the following mercury content:

- Lithium manganese dioxide 0% Hg;
- Silver oxide 0.4% Hg;
- Alkaline manganese dioxide average 0.6% Hg;
- Zinc air 1.0% Hg.

With regard to larger batteries, state-of-the-art zinc carbon cylinders average 50 g/battery and alkaline cylinders average about 33 g/battery, and neither should contain any more than trace quantities of mercury.

Based on these estimates of EU battery consumption and mercury content, the button cell batteries marketed yearly in the EU27+2 would contain 4-5 tonnes of mercury, and the other primary batteries could contain up to 600 kg mercury and remain under the 0.0005% limit. However, based on observations from recyclers and comments by manufacturers, not all larger batteries yet respect the 0.0005% limit, and there is particular suspicion of the mercury content of imported batteries. Therefore the total mercury in these "mass-market" batteries put on the EU market in 2006 could total 5-7 tonnes. However, two other issues will help to put this number into perspective – the statistical evidence of mercuric oxide (or "mercury") batteries, and physical evidence in the waste stream, and the EU production of mercury battery materials.

Mercuric oxide button cells

According to the Comext database (see Table 2-12), 1-3 tonnes of mercuric oxide button cells, or miniature batteries, were imported into the EU from third countries each year during 2002-2006, and an average of about 7 tonnes per year were exported. The PRODCOM database has no information about EU production of mercuric oxide button cells. This is not necessarily conclusive because PRODCOM does not track every minor manufacturer.

Table 2-12 EU imports and exports of mercuric oxide button cells - Comext database

8506 30 30 - MERCURIC OXIDE CELLS AND BATTERIES, IN THE FORM OF BUTTON CELLS								
	1999	2000	2001	2002	2003	2004	2005	2006
EU27_extra import	4	4	6	3	1	2	3	1
EU27_extra export	19	7	63	4	5	17	2	6

Two observations should be made with regard to Table 2-12: First, unless the imported batteries are re-exported, there appears to be a minor (1-3 tonnes) consumption of these button cells in the EU, which would be illegal unless they are used for medical or emergency purposes, or alarm systems. Since these batteries continue to appear in the waste coming to recyclers, any "medical" consumption that may remain could be primarily for hearing aids. In any case, while the mercury content is high (normal estimate 30-40% mercury by weight, as mentioned, but Claushuis (recycler) has said in practice they observe 20-25%), the quantities appear to be low.

Second, if there is an ongoing deficit in EU imports as compared with exports, as demonstrated by the statistics, then this would seem to be compelling evidence of modest EU production. In fact, EU production of these batteries for export would not appear to contravene the Battery Directive. According to the Battery Directive 'placing on the market,' which is banned, means supplying or making available, whether in return for payment or free of charge, to a third party within the Community, and includes import into the customs territory of the Community.

Specifically, according to the Comext database, 1-3 tonnes of mercuric oxide button cells (0.3-0.8 tonnes Hg) were imported into the EU from third countries each year during 2002-2006, which would have been legal as long as the batteries were used for e.g. medical purposes. Further, an average of about 7 tonnes per year were exported. Based on these numbers, and assuming the imports were consumed in the EU, domestic production of mercuric oxide button cells for export would appear to average about 7 tonnes of batteries per year between 2002 and 2006, and 4 tonnes in 2004-5, representing some 1.0-1.5 tonnes of mercury. However, it should be emphasised that EU production of mercuric oxide button cells has not been confirmed, as no EU producer of mercury button batteries has been identified during this research. On the other hand, there is EU production of mercuric oxide battery materials (see below).

Larger mercuric oxide batteries

The EU trade statistics concerning mercuric oxide button cells are insignificant in comparison with the statistics on larger mercuric oxide primary batteries (also known as mercury batteries). Two types of batteries are listed in the Comext database, and the trade of these batteries between the EU and third countries is summarised below in Table 2-13. Whereas the battery tonnage is low when compared to the tonnage of zinc carbon and alkaline batteries used in the EU, the mercury content is very high.

Table 2-13 EU imports and exports of larger mercuric oxide batteries - Comext database

8506 30 10 - MERCURIC OXIDE CELLS AND BATTERIES, IN THE FORM OF CYLINDRICAL CELLS - tonnes								
	1999	2000	2001	2002	2003	2004	2005	2006
EU27_extra import	284	184	253	171	454	165	154	163
EU27_extra export	208	279	84	143	29	15	34	7
8506 30 90 - MERCURIC OXIDE CELLS AND BATTERIES (EXCL. CYLINDRICAL OR BUTTON CELLS) - tonnes								
	1999	2000	2001	2002	2003	2004	2005	2006
EU27_extra import	463	745	500	353	493	334	320	471
EU27_extra export	71	119	69	77	32	13	14	16

Combining these two categories of mercuric oxide battery as in Table 2-14, one would be obliged to conclude that the average quantity of larger mercuric oxide batteries imported into the EU during the 5-year period 2002-2006 was 616 tonnes per year, while the average quantity of batteries exported was 76 tonnes per year. To take 2005 as an example, about 90% of this total were imported by Bulgaria, the Netherlands, the UK and Italy – most of the batteries originating in China, according to UNSD Comtrade statistics. Only the Netherlands did not indicate the source of its imports in the statistics consulted. If the statistics can be trusted,[2] the inescapable conclusion would be that the EU consumes an average (2002-6) of 540 tonnes of mercuric oxide batteries per year, containing approximately 110-130 tonnes of mercury. Again, it is assumed that there is no EU production of these larger mercuric oxide batteries, or else the implied EU consumption would be even higher.

Table 2-14 EU consumption and mercury content of larger mercuric oxide batteries – derived from Comext import/export data

8506 30 10 + 8506 30 90 - MERCURIC OXIDE CELLS AND BATTERIES (EXCL. BUTTON CELLS) - tonnes								
	1999	2000	2001	2002	2003	2004	2005	2006
EU27_extra import	747	929	753	524	947	499	474	634
EU27_extra export	279	398	153	220	61	28	48	23
EU27_implied consumption	468	531	600	304	886	471	426	611
Mercury content @ 22.5%	105	119	135	68	199	106	96	137

Compared to the amount of mercury in all other EU batteries and button cells, these quantities are very high and raise a series of questions:

- To what extent can one trust the statistics?
- If so, are all of these mercury batteries used in medical and military applications?
- If so, is there any incentive in place to encourage such users to replace them with mercury-free batteries?

[2] Other than a number of these batteries reaching recyclers, there is little concrete proof of this level of ongoing EU consumption. Nevertheless, similar and consistent statistics appear year after year in more than one database, in which mercuric oxide batteries are clearly differentiated from other battery types.

- How many of these mercury batteries are collected and recycled, and could they be responsible for the elevated mercury levels observed by battery recyclers?
- What happens to the mercury batteries that are not collected and recycled?

This investigation was able to only partially answer these questions through established contacts with EU battery associations, battery manufacturers, recyclers, etc., as well as through less frequented channels such as second-hand contacts with Chinese authorities and some Chinese battery manufacturers. There is no physical evidence of mercuric oxide battery consumption in the EU at the levels implied by these statistics. And the mercuric oxide batteries for which there is evidence appear to be destined for medical and military applications (Table 2-15), although there are various ways in which some of the batteries may be transferred from those institutions into the public domain, implying insufficient control over the waste stream. Likewise, valid questions may be raised as to whether a hearing aid, for example, deserves an exemption as a "medical" device, or whether all military uses should be considered "emergency" uses, etc.

Table 2-15 Medical and military uses of mercury batteries

Mercuric oxide batteries have long been used in medical institutions for the following devices, among others	Some traditional military applications of mercuric oxide batteries, among others
hearing aids	communications equipment
pacemakers	telemetry devices
defibrillators	navigational aids
foetal monitors	mobile audio and video monitors
hofler monitor	security alert systems
pagers	remote monitoring systems
spirometer alarm	surveillance drones
telemetry transmitter	night-vision goggles
temperature alarm	laser-aimed portable weapons
blood analyzer	military-medical equipment

There are unresolved questions such as what quantities of mercury batteries may be stored in military warehouses, etc. Furthermore, depending on the application and the institution, the resistance to using mercury-free batteries may be rather strong, although some incentive may come from the worsening economics of mercury waste disposal, the decreasing number of mercury battery suppliers, etc.

It has therefore become clear that some commerce in mercury batteries is ongoing, although it occupies a very special niche and involves a rather limited number of suppliers and distributors. Nevertheless, the implications for the environment could be serious, so a further analysis was carried out beginning with a closer examination of the mercury content of waste batteries, as summarised below in section 2.3.6.

EU production of battery materials

Among other findings, this investigation has discovered that there is at least one manufacturer in the EU who appears to produce battery materials for the production of mercuric oxide batteries. In this one known case – and there could well be others – the manufacturer produces zinc-mercuric-oxide metallic strip, apparently for export outside the EU. This manufacturer's annual consumption of mercury amounts to 12-14 tonnes, according to industry sources.

This activity is not technically battery "manufacturing," and it does not contravene the Battery Directive, which permits both EU production of battery components and export of the same. Moreover, the export of these semi-processed materials would not be subject to notification in accordance with Regulation (EC) 304/2003 implementing the Rotterdam Convention on Prior Informed Consent (PIC).

Total mercury consumed in the EU for batteries
Considering the high uncertainty associated with the actual market for larger mercuric oxide batteries, EU mercury consumption in these batteries has been estimated at 2-17 tonnes Hg per year.

EU consumption of mercury in mass-market or low-mercury batteries has been assessed above at 5-7 tonnes, and in mercuric oxide button cells (not including exports) at 0.3-0.8 tonne. Overall, in light of the uncertainties in these estimates, particular attention has been devoted in section 2.3.6 to understanding the quantities of mercury in the battery waste stream. The resulting mass flow balance supports a mid-range estimate of around 16 tonnes of total mercury consumption in batteries.

EU exports of 12-14 tonnes of mercury in battery materials are not considered here as EU consumption, according to the definition put forward in the Summary.

2.3.3 Accumulation of mercury in batteries in society

Calculating the quantity of mercury accumulated in batteries in society is complex for several reasons.

First, an EPBA analysis of waste batteries collected in the Netherlands has shown that primary batteries can take up to 15 years from the date of purchase to appear in the waste stream, although batteries more than 10 years old are less than one percent of the total, as seen in Figure 2-2.

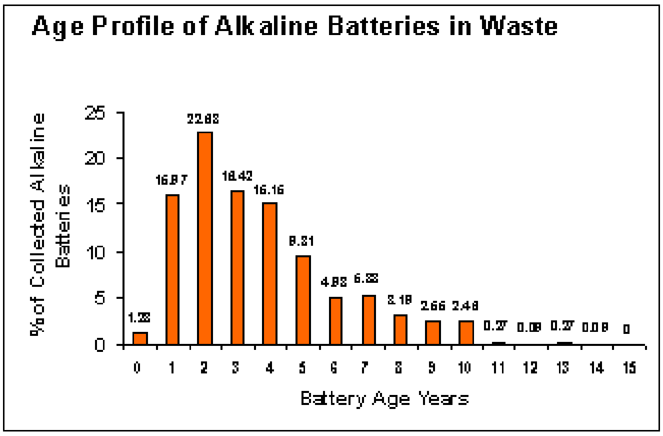


Figure 2-2 Age profile of alkaline batteries collected in the Netherlands (EPBA 2008)

Second, part of the above phenomenon is due to hoarding, in which individuals or organisations may accumulate used batteries for many years before they dispose of their collection.

Third, there has been a marked reduction in the use of mercury in batteries during the last 10+ years, as in most consumer products.

Fourth, the pathways of mercuric oxide batteries in the waste stream – their use, collection rates, recycling, etc. – are not well known.

In 2007 all mixed button cell and larger batteries, both mercury and "mercury-free" (excluding cadmium and lead containing batteries), brought to the recycling company Batrec for recycling contained an average of 300 ppm mercury (Batrec personal communication). This mercury content represents a different battery mix than those treated by most other recyclers. Based as well on other estimates provided below, it is assumed that the EU battery waste stream contains some 150-200 ppm mercury. Based on this metric, it remains to estimate the number of tonnes of batteries circulating in society (i.e., not yet in the waste stream), including those in use, those in closets, those in inventory at stores, those depleted and hoarded, etc. For this measure, in light of the previous discussion and industry input, this analysis assumes a stock equivalent to 36 months of batteries marketed, or some 550-600 thousand tonnes of batteries. At 150-200 ppm mercury this implies an accumulation in society of some 90-110 tonnes of mercury.

2.3.4 Mercury-free alternatives

Table 2-16 summarises button cell battery data, including one mercury-free alternative, although equipment manufacturers have many criteria for selecting the best miniature battery for their product, including cost, nominal voltage, capacity, physical size/shape, and discharge profile.

Table 2-16 Basic data on button cell batteries (Galligan and Morose 2004)

	Alkaline	Silver oxide	Zinc Air	Lithium
Typical mercury content	0.1 - 0.9%	0.2 - 1.0%	0.3 - 2.0%	0
Nominal voltage (V)	1.5	1.55	1.4	3.0
Capacity (mAh)	15 -830	5.5 - 200	33- 1,100	25 - 1,000

Manufacturers are also increasingly marketing mercury-free alternatives to silver oxide, alkaline manganese dioxide ("alkaline"), and zinc air button cell batteries. Some of the mercury-free batteries were initially targeted at the European market (e.g. mercury-free zinc air batteries for use in hearing aids), but most are intended for worldwide use. Several years ago, according to Energizer, the manufacturer of the zero-mercury zinc air battery, this battery was very challenging to produce. Energizer introduced this product in Europe first because it presented a "manageable volume." The performance characteristics were reported to be comparable to the batteries they were designed to replace. The costs of the mercury-free batteries were not readily available; however, based on pricing provided by one manufacturer, there seemed to be a 24-30% premium for the mercury-free miniature batteries compared to the mercury-containing batteries. It is expected that this cost difference will gradually diminish as sales volumes and competition increase for mercury-free miniature batteries (Galligan and Morose 2004).

At least two companies – Sony and New Leader – offer mercury-free silver oxide button batteries for sale on the world market. Sony claims to be among the largest producers of silver oxide batteries in the world, with sales of over 400 million annually. The company produces over 40 models of silver oxide batteries in numerous sizes, and planned already in 2004 to eliminate mercury from its entire product line. According to a press release, Sony silver oxide batteries are used mainly in watches, digital fever thermometers and game products (Sony 2004).

The use of mercury batteries in medical clinics, as well as most military applications, can virtually always be replaced with viable alternatives:

- Alternatives to large mercuric oxide batteries include alkaline, zinc-air, rechargeable nickel-cadmium, and lithium;
- Mercury-containing button batteries can be replaced with zinc-air, lithium, or alkaline button batteries.
- Zinc-air batteries can often be used for telemetry cardiac monitors. It has been reported that these batteries perform better and last longer than mercury-containing batteries. Zinc-air batteries may be especially appropriate for monitors that are in constant use, as zinc-air batteries continue to discharge while in storage.

2.3.5 Battery manufacturers

The most important companies manufacturing batteries in the EU are listed in the following table.

Table 2-17 EU manufacturers of portable primary batteries

Country	Manufacturer	Mercury-containing button cells	Mercury-free button cells	Other mercury-free batteries
ES	Cegasa International SA			X
UK	Duracell Batteries Ltd.	X	X	X
UK	Energizer SA	X	X	X
UK	GP Batteries (UK) Ltd.			X
SI	Iskra baterije Zmaj			X
UK	Moltech Power Systems			X
BE	Panasonic Battery Sales Europe N.V.			X
NL	Philips Consumer Electronics			X
CH	Renata AG			X
FR	Sony France S.A			X
GR	Sunlight Batteries			X
DE	Varta Consumer Batteries			X

While these companies are responsible for the vast majority of batteries sold in the EU, it is useful to note that other companies as well are directly responsible for the marketing of batteries in the EU. This is important in terms of the legal requirement that producers be responsible for their products, and to avoid any “free-riders” with regard to responsibility for the full life-cycle of batteries. Accordingly, in the Battery Directive (Directive 2006/66/ of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC), ‘producer’ means any person in a Member State that, irrespective of the selling technique used (including internet, etc.), places batteries or accumulators, including those incorporated into appliances or vehicles, on the market for the first time within the territory of a Member State on a professional basis.

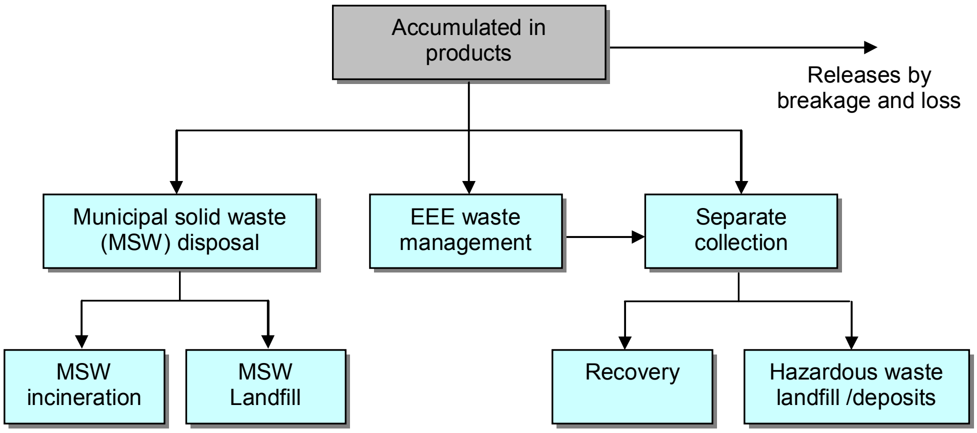
2.3.6 Collection and treatment of mercury batteries

Legislation

Specific legislation regarding collection applies to all mercury-containing batteries. In accordance with the Battery Directive (2006/66/EC) the Member States must take whatever measures are needed to promote and maximise separate waste collection, and to prevent batteries and accumulators from being thrown away as unsorted municipal refuse. The Directive stipulates that collection rates of at least 25% and 45% have to be reached by 26 September 2012 and 26 September 2016 respectively.

Member States must further ensure that, no later than 26 September 2009, all identifiable batteries and accumulators collected undergo treatment and recycling. However, Member States may dispose of collected portable batteries or accumulators containing cadmium, mercury or lead in landfills or underground storage when no viable end market for those metals is available.

The pathways of mercury in waste batteries are shown in the diagram below. Various collection schemes in the different Member States have developed rapidly in recent years with the implementation of the WEEE Directive and the Battery Directive.



Battery recycling

The European Battery Recycling Association, EBRA, represents currently 21 recycling companies in France, Germany, Switzerland, Netherlands, Belgium, Luxembourg, Austria, Sweden, Spain, UK and Czech Republic. According to EBRA, most European battery recyclers are now EBRA members, and the statistics of EBRA are considered to provide the best overview of battery recycling in Europe. The quantities of batteries recycled do not reflect the quantities collected, since a portion of the collected batteries is landfilled or otherwise disposed of in some countries. As an example, of 8,100 tonnes of alkaline batteries collected in Germany, 4,000 tonnes were landfilled in 2005 – because that was less expensive than recycling – as seen in Annex 2.

Quantities of used portable batteries (excluding button cells, rechargeables and large batteries like auto batteries) recycled by EBRA members by country of origin in 2005 are shown in Table 2-18. The rates are above 0.1 kg/capita in France, Belgium, Switzerland, Austria and The Netherlands. The overall recycling rate in the EU has been estimated at 15% of the volume of batteries sold (Schutz 2007). This is the same estimate used by LCSP (2005), noting that many batteries are still landfilled or incinerated in Europe, and the overall collection rate is low.

Table 2-18 Used portable batteries recycled by EBRA members by country of origin in 2006 (based on recycling data from EBRA 2007)

Country of origin	Tonnes collected for recycling	Kg per capita
Switzerland	2,427	0.33
Belgium + Luxembourg	1,681	0.16
France	9,080	0.15
Austria	1,125	0.14
The Netherlands	2,160	0.13
Germany	9,019	0.11
Sweden	679	0.08
Ireland	113	0.03
Spain	688	0.02
Portugal	183	0.02
Greece	193	0.02
UK	454	0.01
Other EU countries	527	
Rest of the world	2,540	
Total	30,869	0.06

In a report for the European Commission, Bio Intelligence Service (2003) distinguished among three approaches to battery collection and recycling:

- Countries where separate collection of all portable batteries is well developed (Austria, Belgium, France, Germany, The Netherland and Sweden): 45% or more of portable batteries available for collection are estimated to be collected, depending on the country.
- Countries where separate collection of NiCd batteries is well developed (Denmark, Norway): 40 to 50% of spent NiCd are collected.
- Countries where separate battery collection is not well developed: 0 to 15% of portable batteries entering the waste stream are estimated to be collected, depending on the country.

According to the report (and contrary to the experience of Germany cited above), about 90% of total portable batteries that are collected are believed to be subsequently recycled.

EBRA members in the EU15 recycled 28,432 tonnes of carbon zinc, alkaline manganese and zinc air cylinders in 2004, and 21,797 tonnes in 2005. Based on recycling data from EBRA (2007), EBRA member companies recycled nearly 31,000 tonnes of cylinder portable batteries in 2006, including some from non-EU countries. Again, the batteries collected from EU countries and recycled amounted to about 15% of the batteries marketed in the EU in 2006. The following chart (Figure 2-3) shows the collection rates (not to be confused with recycling rates) actually achieved in 7 European countries in 2004.

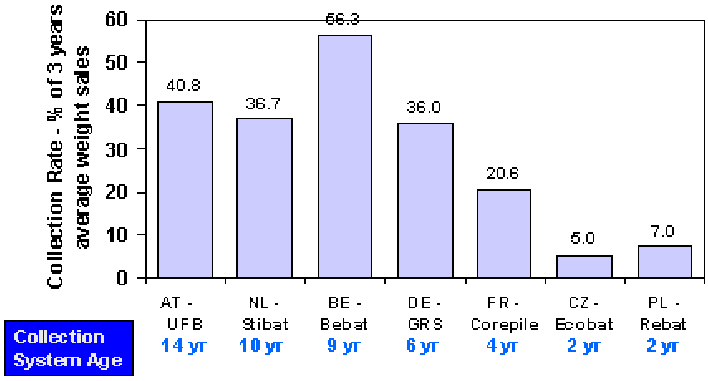


Figure 2-3 Collection rates actually achieved in 7 European countries during 2004 (EBRA 2006)

The quantity of recycled button cells has increased from about 38 tonnes in 2002 to 70 tonnes in 2006 – mostly recycled in France (22 tonnes), Spain (6 tonnes), Sweden (5 tonnes), the Netherlands (23 tonnes) and Switzerland (14 tonnes) – as shown in Figure 2-4. Of the 70 tonnes recycled by EBRA members in 2006, about 56 tonnes originated from the EU25 (EBRA 2007). The EU-origin button cells recycled amounted to about 8% of the button cells marketed in the EU in 2006 – contrary to the general impression that button cells are recycled at a higher rate than larger batteries.

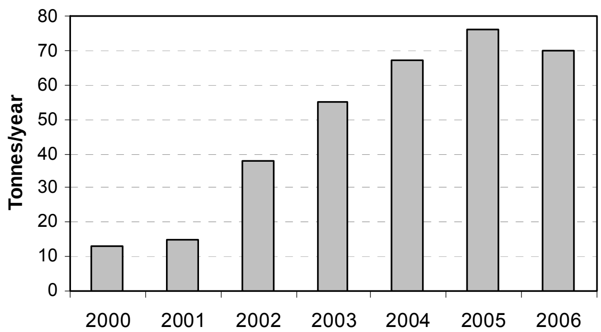


Figure 2-4 Button cells recycled by members of the European Battery Recycling Association, EBRA (EBRA 2007). Please note that the number of members has changed during the period.

The battery waste stream and mercury content

According to EBRA, the average level of mercury in general purpose batteries (not including button cells) is still significantly higher than the 5 ppm permitted by the 1999 Battery Directive, at least partly due to the uncontrolled import from overseas of electronic devices containing batteries (EBRA 2006).

In Germany, GRS reported that the average mercury content of general purpose batteries (not including button cells) was approximately 60 ppm in 1998 and 100 ppm in 2002. A minority of general purpose batteries produced by factories in Southeast Asia and imported into the EU still contained significant amounts of mercury (EC 1997). France reported that Hg in recycled batteries (not including button cells) was 250 ppm in 1998, 109 ppm in 2003 and 40-70 ppm in 2005. The Environmental Impact Assessment (2003) for the Battery Directive noted that collected batteries in several European countries reported average mercury concentrations between 250 and 600 mg/kg for "mixed cells," i.e., including button cells.

With regard to button cells in particular, in 2004 Belgium reported 20% average mercury content in “mixed” button cells, suggesting a significant portion of them must have been mercuric oxide button cells, and 104 ppm in alkaline batteries. When Germany recycled 76 tonnes of button cells in 2004 (also accumulated from previous years), they recovered 5 tonnes of Hg or about 6.6% Hg content. One might infer from both of these cases that mercuric oxide button cells are not routinely well separated from other button cells, at least partly because they are not well marked and they are difficult to recognize as “mercury” batteries.

In response to 2005 stakeholder consultations, Finland reported that it collects mercuric oxide batteries separately, and reported one tonne of “mercury” batteries collected in 2000, which were sent to Batrec in Switzerland for recycling. The Finns speculated that they collected only half of the mercuric oxide batteries that were put in the waste stream that year. Meanwhile, Finland implemented the EU battery legislation in 1999, and consumption of mercuric oxide batteries is reported to have declined greatly since then.

The only recycler that has reported recycling all waste batteries mixed together (button cells, “Hg-free,” and mercuric oxide batteries, but excluding lead and cadmium batteries) is Batrec in Switzerland, which in 2003 recovered 0.9 kg of mercury for every tonne of mixed batteries recycled – equivalent to 900 ppm (personal communication). This is useful empirical information because in most other cases large mercuric oxide batteries are separated before recycling, and no specific information has been uncovered with regard to quantities of mercuric oxide batteries recycled.

Batrec has prepared a very detailed mass balance of its recycling operations (Batrec 2007), and demonstrated that in 2007 the overall mercury content of all batteries mixed together (excluding lead and cadmium) had decreased to about 300 ppm Hg, divided between about 50 ppm Hg for “Hg-free” general purpose batteries, and significantly more for the button cells. Batrec estimated that the Hg content of all batteries in the EU27+2 waste stream should be about the same as they observed for 2007 (personal communication). However, failing to identify another recycler with a similar battery waste mix, for purposes of this analysis 150-200 ppm Hg has been selected as a conservative compromise for all batteries mixed together, and the range of 40-70 ppm Hg for general purpose batteries. If one assumes that slightly fewer batteries entered the EU waste stream than were consumed in the EU in 2007, this implies 27-36 tonnes of mercury in the overall battery waste stream, of which 8-12 tonnes are contained in general purpose batteries, leaving the remaining 19-24 tonnes that must be contained in the button cell batteries, implying an average button cell mercury content of some 3-4.5%, which surely demonstrates the existence of mercuric oxide button cells in the battery waste stream.

However, if button cells are going into the waste stream with that level of mercury content, it makes no sense to assume that new button cells are being put on the market with 1% or less mercury content. In short, the 150-200 ppm mercury content of the battery waste stream makes sense only if the mercury content of the batteries being put on the market is higher than state-of-the-art levels. In light of the reduction of the mercury content of battery waste observed by Batrec from 900 to 300 ppm over 4 years, it makes sense to assume a proportional reduction over three years with regard to batteries put on the market. Therefore, if the batteries going into the waste stream in 2007 were assumed to have 150-200 ppm mercury, and if one assumes 1-3 years average delay from the time a battery is marketed until it enters the waste stream, then the overall mercury content of all batteries being marketed in 2007 could not be less than about 70-100 ppm, or 13.3-19 tonnes total (16 tonnes average) mercury, assuming 190,000 tonnes of batteries marketed. This accommodates some ongoing but very limited participation of mercuric oxide batteries in the EU battery market.

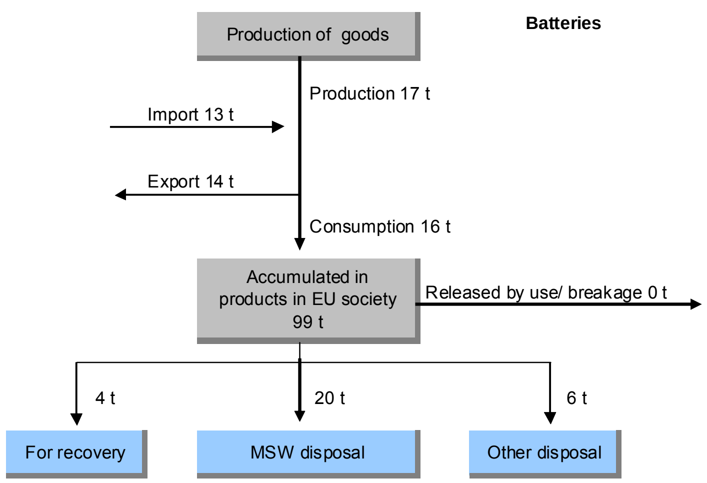
While both Batrec and Claushuis recycle larger mercuric oxide and other special batteries, neither has reported volumes of batteries that would support anything approaching the trade figures presented in Table 2-13 that suggest EU consumption of 500+ tonnes of mercuric oxide batteries. It is conceivable that military organisations are consuming larger quantities of batteries and disposing of them as hazardous waste or in landfills in such a way that the batteries scarcely appear in normal waste and recycling statistics. In addition, a certain volume of mercuric oxide batteries may disappear into hospital waste. But this investigation has been unable to find concrete evidence to support significant EU consumption of these batteries.

The waste pathways for general purpose and button cell batteries differ somewhat. “The main disposal route for spent batteries is landfilling. It is estimated that 75% of the disposed spent batteries are being landfilled” (Bio Intelligence Service 2003). It may be speculated that almost no general purpose batteries are disposed of as hazardous waste, but this is less true for button cell batteries. This analysis has divided waste batteries into two main groups: 1) general purpose batteries and 2) button cells.

For this analysis it is assumed that 15% of the larger batteries are recycled, and a somewhat lower percentage of the button cells. It is also assumed that as much as 20-30% of the button cells may go to final disposal (e.g. deep underground), and that around 5% of general purpose batteries and 10% of button cell batteries are stored or hoarded and do not reach the waste stream. This leaves about 75% of general purpose batteries and about 50% of button cell batteries going to solid waste, i.e. landfill or incineration. These mass flows are summarised in the diagram in section 2.3.7 below.

2.3.7 Mercury mass balance

The previous data on the flow of mercury in batteries are summarised in the following flowchart.



2.4 Dental amalgam

2.4.1 Mercury use and emissions

The use of mercury in dental tooth fillings comprises a significant part of the annual mercury consumption in the EU. The traditional “silver fillings” used to fill dental cavities contain approximately 50% mercury. While the potential health effects of amalgams continue to be debated, there are also various pathways of mercury releases into the environment that deserve closer attention.

Estimates by industry contacts of the annual market for Hg amalgam in 2007 converge on the range of 80-110 tonnes Hg for the present EU market, of which about 70% is used as pre-measured capsules of mercury, and 30 % as liquid mercury. The capsules are preferred (but more expensive than using bulk mercury) in order to limit spillage and occupational exposure, enhance amalgamation and ensure that quantities of metals are mixed together in the right proportions. The estimate of 80-110 tonnes is consistent, on the basis of relative population, with a number of country reports of national consumption of dental mercury. For the questionnaire of this study Germany (2006) estimated 10 tonnes of mercury, France (2004) estimated 35 tonnes (but this appears to be an estimate of total amalgam weight, and therefore represents 17.5 tonnes of mercury), the UK (2006) estimated 6.6 tonnes, the Netherlands (2004) 2.4 tonnes, Slovenia (2004) 0.023 tonnes, and the Nordic countries together consumed probably no more than one tonne of mercury in amalgams in 2007. One industry response to specific questions for this study estimated the mercury consumption of the Western European countries at 50-60 tonnes, and for Eastern European countries at 40-50 tonnes, including some non-EU countries

The general trend of dental mercury consumption in the EU is declining. It is estimated that about 21 million amalgam fillings were placed in Germany in 2004, and according to industry this number was lower in 2007. Presently, it is estimated that about 40% of German dentists no longer place amalgam fillings (ref. Ivoclar Vivadent). A Swedish company has estimated that 97% of fillings in Sweden are now mercury-free (personal communication).

The complex pathways of dental mercury may include amalgam waste (generated by drilling out a previous filling) going to the wastewater system; the excess material carved from a new amalgam filling; the removal of teeth containing amalgam; unused amalgam going to solid waste; mercury emissions directly to the air; the traps, filters and other devices in dental clinics designed to remove mercury from the wastewater; and various waste disposal alternatives.

Trends
In many higher income countries, dental use of mercury is now declining (Finland comments, 2006; ADA comments, 2006). Among others, Sweden, Denmark, Norway and Finland have implemented measures to greatly reduce the use of dental amalgams containing mercury. However, the speed of decline varies widely among countries, so that dental mercury use is still significant in most countries of the EU, while in Sweden and Denmark it has nearly ceased. In lower income regions, changing diets and better access to dental care may actually increase mercury use temporarily, especially where the cost of treatment is most critical. Based upon information from industry contacts who have already observed a decline in EU dental mercury use, a gentle decline will continue unless influenced strongly by national or EU initiatives, in which case the decline would be steeper.

2.4.2 Imports and exports

Contacts with industry have suggested that some 40-50% (and generally increasing) of EU production of dental amalgam materials may be exported, while 20-30% (fairly stable) of EU consumption may be satisfied by imports. Assuming EU consumption of some 90-110 tonnes of Hg, this implies EU production of 130-140 tonnes (mercury content), imports of 20-30 tonnes, and exports of 50-70 tonnes.

The situation with regard to mercury-free alternatives is slightly different. It is estimated by industry contacts that 75-85% of the EU consumption is satisfied by EU producers, and only 15-

25% is imported. Likewise it is estimated that 60-70% of total EU production of mercury-free alternatives is exported.

It should be mentioned that there is some industry concern about national or EU-level restrictions on EU exports of amalgam, especially in capsules, as improved access to capsules would provide lower-income countries with a safer product than the present general practice of mixing amalgams by hand from liquid mercury.

2.4.3 Accumulation of mercury in society

"Human inventory"
The extent of dental use of mercury in the EU is highly variable from one country to another, and there are a range of estimates of the amount of mercury carried in people's mouths.

Sweden has estimated that there are about 40 tonnes of mercury in the teeth of its citizens (KemI 2004), which is equivalent to about 4.5 g average for each of Sweden's 9 million citizens. However, since only 74% of Swedes have fillings, the actual average is closer to 6 g mercury per citizen with fillings. As a national policy, the use of mercury fillings in Sweden is becoming increasingly rare; the country estimated its annual use of mercury for dental applications at only about 100 kg in 2003 (KemI 2005).

It has been estimated that the human dental inventory in France was about 100 tonnes of mercury, which is an average of less than 2 g per person in the mouths of France's population of around 60 million. (Piren-Seine 2004, as cited by FNADE 2005) It has been estimated for the EU-15 and EFTA countries that an inventory of 1,300 to 2,200 tonnes of mercury is present in the dental fillings of the population (Hylander 2002; EC 2004). This estimate may be somewhat high as the overall use of dental amalgam in the EU declines.

In order to determine the dental mercury load of the average person at the time of death – generally assuming that virtually all mercury in amalgams is released during cremation – various countries have developed estimates. While the range of estimates is large, they converge at approximately 3 g mercury per person cremated. Since most deaths are among older persons, one might assume that virtually all of them have mercury fillings, whereas many young persons do not. On the other hand, because they have fewer of their natural teeth, on average, older persons tend to have less amalgam in their mouths than the average adult (DEFRA 2004). Therefore, in very general terms, for the entire EU-27+2 population of some 500 million persons, one might conservatively assume that three-quarters of the population has an average of 3 g of mercury in their mouths, or that the entire population has an average of something over 2 g of mercury in their mouths – both sets of assumptions leading to an estimate of over 1000 tonnes "human inventory" of dental mercury. This corresponds to an average filling lifetime of 9-10 years in the EU, which is in the middle of the range of typical estimates.

Clinic stocks
Until fairly recently, most dentists had stocks of liquid mercury in their clinics which they used, in the past, to make dental amalgams by hand. Since relatively few Member States in the EU have made efforts to recover these stocks of mercury, it is reasonable to assume that there remain substantial quantities of mercury in storage in dental clinics. These stocks of mercury are at risk of accidents, improper disposal or other releases due to neglect. They are quantified in section 3.1.4.

Likewise, virtually all dentists have on hand stocks of mercury in capsules as part of their regular business inventory. If they have, typically, two to four months' inventory, then based on total

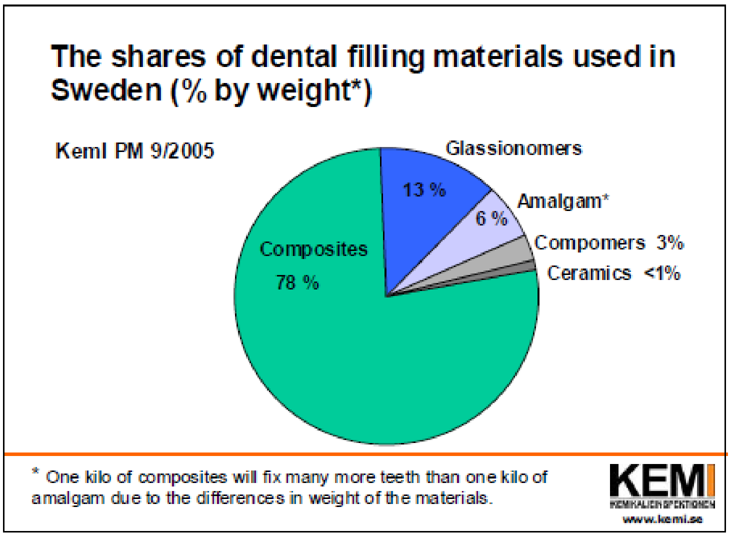
EU consumption of 90-100 tonnes per year, there may be 15-30 tonnes of mercury in the clinic inventory.

2.4.4 Mercury-free alternatives

The ongoing debate about the viability of mercury-free alternatives to amalgam fillings is mostly a debate about changing habits, about appropriate dental training, about choosing the proper alternative, about experience with new materials, etc. The Swedish experience, among others, has proven that there are very few cases where a compelling argument can be made that an amalgam filling is "necessary".

Alternative materials

Materials that are used for the restoration of the form and function of teeth can be divided into materials applied through direct and indirect procedures. In a direct procedure, the material is introduced in a plastic state and hardens in the tooth, while in an indirect procedure, an impression is usually made, which is then used by a dental technician to make an inlay or crown. Since the placement of amalgam is considered a direct procedure, the appropriate mercury-free alternatives are also typically applied through a direct procedure.



Source: KemI 2005

As can be seen above (estimate from 2005), the most common alternatives in recent years are different types of composites (i.e., polymer resin based materials), which may replace almost all uses of amalgams. Other materials used are ceramics (including porcelain) and glass ionomers, or combinations of materials, e.g. "compomers" that are modified composites. There are also prefabricated ceramic cones, which are pressed into composite fillings to reduce shrinkage of the filling.

In line with growing consumer interest, there is constant research into the development of new materials. One example is hydrated ceramics, which form a body-compatible substance that is integrated chemically and biologically into the tissue. Another example is the technique of mixing a ceramic powder into composite material that gives the filling increased strength.

Cost of alternatives

Of the total dental invoice for placing an amalgam filling, the cost of the amalgam materials is typically not more than 5% of the total cost of the procedure. Although some mercury-free alternative materials may be twice that cost, it is clear that it is not the cost of the dental materials that makes the invoice higher.

Nevertheless, there are a number of reasons that most dentists continue to offer amalgam fillings at a significantly lower price. While the cost of a dental procedure is rarely discussed with the patient in advance, nevertheless it is assumed that the price differential is an important consideration for many dental patients. An industry contact noted that a private Swedish dentist may charge €150-200 for a composite filling, but some of that cost is now reimbursed by health insurance, whereas in most cases amalgam fillings are no longer reimbursed in Sweden. This has made the relative cost of amalgam fillings vs. composite fillings roughly equivalent in Sweden (KemI 2005).

While most dental professionals continue to charge somewhat less for amalgams, it is increasingly clear that the full "external" costs borne by the rest of society are high, taking into account the full range of environmental and potential health ramifications (Hylander & Goodsite 2006; Maxson 2006), as further discussed in section 0.

2.4.5 Suppliers of amalgams and alternatives

There are about a dozen European producers of dental amalgam capsules, and several of them also supply liquid mercury. In addition, there are many more suppliers of mercury-free alternatives, of which the most important are listed in Table 2-19 overleaf (personal communications with Ivoclar Vivadent, Nordiska).

Table 2-19 Producers of mercury amalgams or capsules and mercury-free filling materials

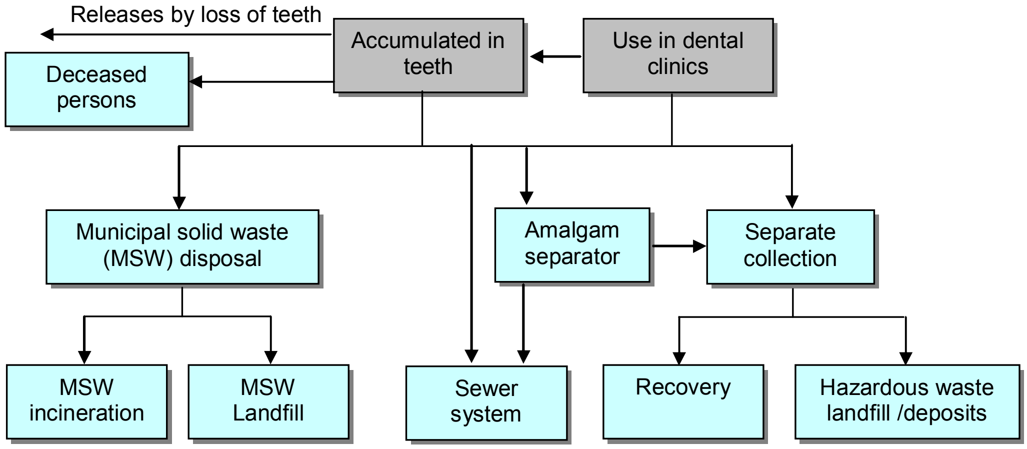
Country	Company name	Mercury amalgams or capsules		Mercury-free filling materials	
		EU Producer	Distributor	EU Producer	Distributor
Canada	Nordenta		X	X	X
CH	Coltène Whaledent	X	X	X	X
CZ	SAFINA, a.s.	X	X	?	?
DE	3M Espe			X	X
DE	Dentsply			X	X
DE	DMG Chemisch Pharmazeutische Fabrik GmbH	X	X	X	X
DE	Dr. Ihde Dental GmbH	X	X	X	X
DE	Heraeus Kulzer Dental GmbH & Co. KG			X	X
DE	Kaniedenta Dentalmedizinische Erzeugnisse GmbH & Co. KG			X	X
DE	M & W Dental	X	X		
DE	Merz Dental GmbH	X	X	X	X
DE	S & C Polymer GmbH			X	X
DE	Voco GmbH			X	X
ES	Madespa S.A	X	X	?	?
FR	Dentoria SAS	?	X	X	X
FR	Specialities Septodont	X	X	X	X
GR	DMP Dental Materials Ltd	?	X	X	X
IT	Kerr			X	X
LIE	Alldent AG	?			
LIE	Ivoclar Vivadent AG	X	X	X	X
NL	Cavex Holland BV	X	X	X	X
SE	Ardent AB (Ivoclar Vivadent)	X	X	X	X
SE	Nordiska Dental AB	X	X	X	X
UK	Engelhard	X	X	X	X
UK	SS White Group		X	X	X

2.4.6 Mercury in dental wastes

Most dental mercury waste results from the removal of previous fillings from patients' teeth. Together with waste amalgam carved from new fillings, removed teeth, etc., these dental wastes typically follow several main paths. They may be captured at the dental clinic for subsequent recycling or disposal, they may be flushed down drains that lead to the general municipal wastewater system, they may be placed in special containers as medical waste, or they may be put into the municipal waste stream.

The pathways of mercury in dental amalgam differ significantly from the other products as shown in the diagram below. The fate of the dental amalgam to a large extent depends on whether amalgam separators are installed in the drain of the dental clinics. Without separators as much as 50-70 % of the total mercury content of the amalgam waste goes down the drain, and dental amalgam is commonly the main source of mercury to municipal wastewater.

The diagram is a simplified illustration of the general flow of mercury through the dental clinic and downstream. Among other details, it does not show, for example, that mercury may be released to the air both within the clinic and from the clinic wastewater system, nor does it make clear that mercury may be released by certain dental techniques (e.g. cleaning or polishing mercury amalgams) even when fillings are not placed or removed.



Next to each dental chair most dental facilities have a basic chairside filter (or trap) in the wastewater system to capture the larger amalgam particles, and some have secondary vacuum filters just upstream of the vacuum pump. In addition, separator technologies are now available that can potentially remove over 90% of the mercury from wastewater.

Over many years the piping systems in many dental clinics have accumulated mercury that settles to low parts of the system, sumps, etc., or may attach itself to the inside of a metallic piping system. The slow dissolution and re-release of this mercury may be sufficient, even after dental clinic emissions have been greatly reduced, to exceed wastewater discharge standards, and may serve as a long-term source of mercury to a wastewater treatment facility.

The Community legislation does not specifically stipulate that the drain of dental clinics shall be equipped with amalgam separators, but the Waste Directive (75/442/EEC) requires that waste must be disposed of without endangering human health and the environment. The actual interpretation and implementation as regards dental amalgam wastes varies among Member States. Once collected, the amalgam waste should be considered as hazardous waste and covered by EWC code 18 01 10. It means that amalgam waste will need to be collected separately, kept separate from other waste produced by the practice and consigned to a waste management facility with a licence or permit to handle hazardous waste.

The result of a questionnaire survey carried out by the European Commission in 2005 regarding the actual treatment of amalgam waste in the Member States is shown in Table 2-20. In most of the old Member States (EU 15) amalgam separators are required in both new and established dental clinics, but there remains a large gap in some countries between the mandate and the implementation of the mandate. Typically a minimum dental amalgam separator efficiency of at least 95% is required (e.g. in Austria, France, Finland, Germany, Netherlands, Portugal and Sweden).

In some Member States (e.g. Italy, Ireland, Slovakia, Cyprus) separators are required only in new dental care facilities, while in some of the new Member States amalgam separators are installed in only a few (e.g. Estonia, Latvia and Slovenia) clinics. The situation may have changed in these countries during the last two years, but at the time of the questionnaire below, it was clear that no more than 30-40% of EU dental clinics had installed functioning amalgam separators. It is notable that of the new Member States only Slovenia has reported significant recycling of dental amalgams.

Table 2-20 Member States' replies in 2005 to a questionnaire from the European Commission DG ENV on the use of amalgam separators in dental clinics

Country	Summary assessment
AT	Amalgam separators installed in most or all dental care facilities; tubes contaminated with mercury are kept separately
BE, Brussels Region	No reply
BE, Flemish Region	Detailed and comprehensive legislation on the separation and appropriate treatment of dental amalgam; no information on the implementation
BE, Walloon Region	Amalgam separators installed in most or all dental care facilities; tubes contaminated with mercury are removed
CY	Amalgam separators or filters only installed in modern dental care facilities
CZ	Amalgam separators installed in half of the dental care facilities
DA	No reply
DE	Amalgam separators installed in all dental care facilities
EE	Amalgam separators/filters installed only in a few dental care facilities
ES	No reply
FI	Amalgam separators installed in all dental care facilities
FR	Amalgam separators installed in almost all dental care facilities
GR	More recent health care units are equipped with dental amalgam traps
HU	No reply
IE	Amalgam separators only installed in new dental care facilities, some measures including a study on health care waste are being taken
IT	Amalgam separators only installed in modern dental care facilities
LA	Only a few amalgam separators or filters seem to be installed
LT	No reply
LU	Unclear reply
MT	No reply
NL	Amalgam separators installed in all or most dental care facilities
PL	Separate collection requirement for dental amalgam, implementation not so clear
PT	Amalgam separators installed in most dental care facilities; vast majority of dentists no longer use amalgams containing mercury
SK	Amalgam separators only installed in modern dental care facilities, older ones will acquire them.
SL	A generic requirement to install dental amalgam separators has been most likely adopted. The implementation is still outstanding and the reported collection rate for dental amalgam is still to be improved
SV	Amalgam separators installed in most dental care facilities, rinsing campaigns targeting tubes contaminated with mercury have been carried out
UK	No reply

Data on dental amalgam waste by country is shown in Table 2-21. A comparison between the countries is complicated by the fact that the mercury content of the waste seems to be different among the Member States. Finland and the Netherlands as well as FNADE in France (FNADE 2005) estimated the mercury content of the waste at about 50% while Germany estimated the mercury concentration of the waste at 3-5%. The difference apparently reflects actual differences in the composition of the waste, where the 50% represents waste from mercury traps and the 3-5% waste from separators. The available data represent 57% of the EU27+2 on a per capita basis. The total amount of mercury can be estimated at a maximum of 36 tonnes if it is assumed that the mercury content of the waste is 50% for those countries reporting only on the amount of waste. The data mainly represent countries with amalgam separators in most dental clinics, and the total for EU27+2 cannot be reasonably estimated by a simple extrapolation.

Table 2-21 Collected dental amalgam waste by Member State (based on questionnaire and stakeholder responses)

Country	Year	Tonnes waste	Tonnes mercury	Treatment
BE, Flanders	2005	5		The waste consist of amalgam + cassette from separator, export for recovery
CH	2007	3		2.5 t recovered either in Switzerland or elsewhere, 0.5 tonnes incinerated
CZ	2003	1.1		
CZ	2007	3.0	~1.5	Safina (Mr. Bolscha) said that they process about 3 t of dental amalgam waste/ yr from CZ and surrounding countries.
DE	2003	70	2.0-3.5	Recycled and used for battery production in the EU
DK	2005		0.9-1.9	0.8-1.7 t exported for recovery, 0.05-0.1 t landfilled or incinerated, respectively
FI	2000	1.0-1.2	0.5	Recycling rate of 80%, distilled mercury is exported
HU	2006	0.004		Landfilled or incinerated
FR	2004	15-20	7.5-10	Recycled within France
NL	2003	3.9	2	
NO	2006	12		
PT	2002	0.4		
SE	2005	6		Exported for recovery
SL	2006	0.9		0.84 t recovered within Slovenia, 0.03 t incinerated and 0.0004 kg landfilled
UK	2006		7	3 t recovered in the UK, 3 t exported for recovery and 1 t incinerated. In 2002 dental amalgam totalled 6.28 t mercury; of this 3.3 t was emitted to the sewer while 2.98 was sent for disposal/recycling

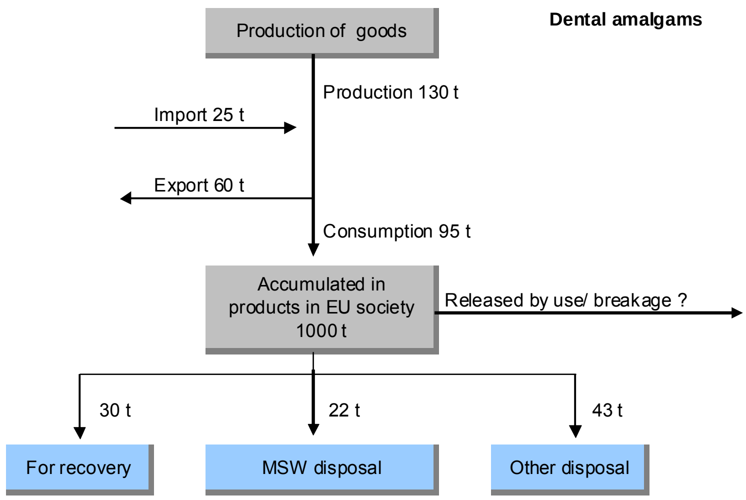
Based on EEB (2006), the quantity of mercury in the dental mercury waste stream approximates the nearly 80-110 tonnes consumed annually. If is it assumed that 95% of the dental clinics in the EU have traps that on average collect 40% of the mercury waste, and that 30-40% of the clinics are equipped with separators collecting another 55% (total trap + collected = 95%), then it may be roughly estimated that for the EU27+2 the mercury in total 55-60 % of the waste is collected corresponding to 45-65 tonnes mercury.

Some Member States have reported that a part of the collected waste ends up in waste incineration or landfills, and this is probably true for most countries, and it is estimated that only 40-60% of the amalgam waste is recycled, corresponding to approximately 20-40 tonnes, while the remaining part ends up in waste deposits, including underground mines.

Of the remaining mercury in the waste stream, 20-30 tonnes are removed from circulation and not released to the environment, such as through deep underground disposal, while the remaining 35-50 tonnes are estimated to ultimately end up in various environmental media, of which 45-60% to the soil (via wastewater sludge to land disposal, via burial, via atmospheric deposition following cremation or wastewater sludge incineration, etc.), and 5-15% to the atmosphere. In addition, important amounts are released to surface waters (10-20%) and eventually to groundwater (5-15%).

2.4.7 Mercury mass balance

The obtained data on the flows of mercury from dental amalgams are summarised in the flowchart below. In order to follow the general flowchart format, all mercury not recovered or ending up in municipal solid waste (MSW) is simply indicated as “other disposal” (see the text above for more details about the actual fate of this mercury). It should be noted that emissions from cremations are included in “other disposal”. Small amounts of mercury may be released from fillings during use, and small amounts may be lost to the environment with broken fillings. The actual amounts are not discussed in this study.



2.5 Measuring equipment

Mercury is used today in a range of measuring equipment. This chapter includes the following current applications of mercury:

- Thermometers:
  - Mercury-in glass thermometers;
  - Mechanical mercury thermometers with a dial for remote control;
- Manometers;
- Barometers;
- Blood pressure measuring devices:
  - Sphygmomanometers;
  - Strain gauges;

- Hygrometers;
- Hydrometers;
- Tensiometers;
- Gyrocompasses;
- Mercury-containing reference electrodes;
- Hanging drop mercury electrodes.

Furthermore, the chapter briefly describes the following applications for which current use of mercury devices in the EU has not been confirmed:

- Gas flow meters;
- Coulter counters;
- Permeters.

Porosimeters have in some texts been described as mercury measuring equipment, but since the mercury is used in porosimeters as an analytical chemical, it is included in this study under “miscellaneous applications”.

Legislation
Mercury in measuring devices has recently been regulated by Directive 2007/51/EC of the European Parliament and of the Council of 25 September 2007 amending Council Directive 76/769/EEC relating to restrictions on the marketing of certain measuring devices containing mercury.

According to the Directive, mercury may not be placed on the market: (a) in fever thermometers; and (b) in other measuring devices intended for sale to the general public (e.g. manometers, barometers, sphygmomanometers, thermometers other than fever thermometers). The Member States shall apply these measures from 3 April 2009. The restriction in the Directive does not apply to: (a) measuring devices more than 50 years old on 3 October 2007; or (b) barometers (except barometers included in point (a)) until 3 October 2009.

The prohibition of mercury in measuring devices, in particular the ban on mercury in fever thermometers, will greatly influence the total use of mercury in measuring equipment. Below are provided estimates on the consumption of mercury before the Directive enters into force.

Assessment of options for reducing mercury in measuring equipment
Options for reducing the mercury input to society in measuring equipment are assessed in section 6.5. This chapter provides next a relatively detailed description of the use of mercury in measuring equipment as background information for the analysis of policy options.

2.5.1 Applications of mercury and alternatives

2.5.1.1 Thermometers

Mercury thermometers may, in principle, be used for manual reading of all temperature measurements in the interval from the freezing point of mercury, -39°C, up to about 800°C, with an accuracy of 0.01°C. For measurements at lower temperatures, down to -58°C, a mercury-thallium thermometer may be used, while for even lower temperatures hydrocarbons like toluene or pentane are used. For higher temperatures than 800°C, thermometers with a gallium filling are used.

Three types of mercury-containing thermometers have traditionally been used in the EU:

- Mercury-in-glass thermometers:
  - Medical thermometers;
  - Ambient temperature thermometers (wall thermometers);
  - Laboratory thermometers;
  - Thermometers for combustion and industrial processes.

- Mechanical mercury thermometers with a dial; and

- Contact thermometers (electric thermoregulators are included in chapter 2.6.1.2).

The most common mercury thermometers consist of mercury encased in a thin glass tube that rises and falls (expands and contracts) with temperature. This thermometer has traditionally been widely used as a fever thermometer, in laboratories, as an ambient temperature thermometer and for temperature monitoring of machines, combustion processes and industrial processes.

The mercury content of medical thermometers ranges from 0.5 to 1.5 grams (Floyd *et al.* 2003).

The mercury content of thermometers used for laboratories and in industry range from 1 to 20 g Hg per thermometers, with an average content of 3-4 g.

A mercury-in-glass thermometer with a U-shaped tube can be used to indicate minimum and maximum temperature during a given period of time.

Mercury dial thermometers consist of a mercury filled metal tube with a bourdon coil and a pen or needle for reading the temperature. They are applied mostly in the process industry and for marine applications. Similar thermometers for high temperature measurements, e.g. in foundry applications for measurements of the temperature of diesel exhaust, are also designated as pyrometers. For remote control of large engines or combustion processes, thermometers consisting of a sensor on the machine and a mercury filled capillary up to 40 m long connecting the sensor to a gauge in the control room have been and may still be in use. The mercury content ranged from about 5 to 200 g (Maag *et al.* 1996). These thermometers have mainly been used for marine engines and within the power sector.

For long-distance transport in e.g. refrigerated containers, insurance companies require continuous monitoring and verification of the temperature during the whole transport period. According to a Swedish study, in the late 1990s a manually supervised instrument containing 190 g mercury dominated the market for marine transport (Gustafsson 1997, as cited by Lassen and Maag 2006). Today, automatic devices without mercury, approved by international insurance companies for control of refrigerated containers, are marketed.

EXAMPLE:

" Viele Varianten möglich, Spezialwünsche werden berücksichtigt! Einfache Standard-Typen, sowie eichfähige und staatlich geeichte Instrumente mit amtlichem Schein erhältlich."

Manufacturer: Amarell GmbH & Co, Germany

Source: http://www.amarell.de/default.htm

Alternatives

A number of different types of mercury-free thermometers are marketed, among these:

- Mercury-free liquid-in-glass thermometers;
- Dial thermometers;
- Electronic thermometers (thermocouple and resistance thermometers);
- Infrared thermometers.

The thermocouple thermometers, platinum resistance thermometers and infrared thermometers are all based on a thermoelectric principle and can, via an analogue-to-digital converter, be connected to a data logger. These are sometimes jointly designated electronic thermometers or digital thermometers.

Mercury-free liquid-in-glass thermometers

The liquid-in-glass thermometer is the most common replacement of the mercury thermometer at temperatures up to 250°C. Its appearance and structure are similar to mercury-in-glass. The liquids used in such glass thermometers include common organic liquids such as alcohol, kerosene and citrus-extract-based solvents that are dyed blue, red or green. Also thermometers containing a gallium-indium mixture have been reported. These liquid-in-glass thermometers can directly replace mercury room temperature thermometers.

Coloured liquid thermometers for professional use are widely marketed. The price is roughly the same as for mercury thermometers. Most mercury-free liquid-in-glass thermometers are not suitable for accurate measurements at 0.1°C resolution, but the mercury-free thermometers are fully suitable for less accurate measurements.

A liquid high-precision thermometer, PerformaTherm™, has recently been introduced by the US manufacturer Miller and Weber, Inc. (Miller and Weber 2008). According to the manufacturer PerformaTherm™ meets all ASTM standards for accuracy, tolerance and uncertainty. Each thermometer is supplied with a two-page report of calibration. According to the manufacturer the thermometer meets the same specifications as mercury-in-glass thermometers as concern tolerance (± 0.1ºC), uncertainty at ice (± 0.02ºC), uncertainty over range (± 0.05ºC) and response time (< 3 min.). According to the manufacturer the proprietary blue liquid is biodegradable, nontoxic, noncaustic, and nonhazardous. In the EU the thermometers are supplied by Poulten Selfe & Lee Ltd (UK), among others, and are marketed for the temperature range -38 - 155ºC. The liquid of the thermometer has according to the manual a tendency to separate, especially during storage or transit and shall be rejoined using cooling methods. According to information obtained from some users in the petrochemical industry the slower response time and the separation of the liquid are serious restraints for the use of the thermometers. It has within the scope of this study not been possible to make a further assessment of the applicability of the PerformaTherm thermometers.

A recent €250,000 research project by the Fraunhofer Institut Silicatforshung "Quecksilberfreie Präzisionsthermometer" has investigated the options for manufacturing high precision (<0.2 degree resolution) liquid-in-glass thermometers (Deichmann *et al.* 2007). According to available information, a useful liquid has still not been developed.

Dial thermometers

A number of dial thermometers for <u>manual reading</u> are marketed for use in industry. These thermometers may consist of a liquid- or air-filled metal cylinder with a dial for manual reading. Another type is a bimetal dial thermometer that senses and indicates temperature using a bimetal coil, which consists of two dissimilar metals bonded together. These materials have different coefficients of thermal expansion and, when subjected to temperature change, rotate the coil.

These thermometers are available for measuring temperatures in the range from about -70°C to 600°C. The dial thermometers have typically replaced mercury-in-glass thermometers for the temperature range above 250°C, e.g. for measuring the temperature of exhaust gases of diesel engines. The price of a typical dial thermometer for a diesel engine – about 400 DKK (53 euro/piece) – is some 2-4 times the price of a similar mercury thermometer (Lassen and Maag 2006).

A number of dial thermometers for <u>remote measurement</u> of temperature in industry, power plants and marine applications are available as alternatives to mechanical mercury thermometers for remote temperature reading. The price of the remote type thermometers is also typically about 2-4 times the price of a similar mercury thermometer (Lassen and Maag 2006).

Electronic thermometers

Electronic thermometers with a digital display and/or automatic data logging make up an increasing part of the thermometer market. The most common types are based on thermocouples, thermistors or resistance probes.

Platinum resistance thermometers (PRTs) and thermistors both rely on the known variation of electrical resistance with temperature of a specially constructed resistor to convert temperature into a measurable electrical property.

Thermistors have stabilities approaching a few thousandths of a degree Celsius per year when properly constructed, and are highly sensitive (approximately 4% change in resistance per degree Celsius). However, the usable temperature range is limited to not more than 100°C for a single thermistor, and the approximate maximum temperature of use is 110°C (Ripple and Strouse 2005). The best stability is obtained with thermistors coated or encapsulated in glass.

Platinum resistors have a substantially wider operating range compared to thermistors, but they have a sensitivity 10 times smaller (approximately 0.4% change in resistance per degree Celsius).

Thermocouples (TCs) consist of two lengths of dissimilar metals, joined at one end to form a measuring junction. Each length, referred to as a thermoelement, develops a voltage (or more accurately, a thermoelectric electromotive force) along its length wherever the thermoelement passes through a temperature gradient (Ripple and Strouse 2005). Different thermocouple types can be used for applications in temperature ranges from -40°C to +1800°C. Thin-film resistance thermometers provide accuracy over a wide temperature range (from -200°C to 850°C).

Electronic thermometers are used throughout industry for automatic temperature measurements. For some applications, e.g. diesel engines for marine applications, the automatic measurements may be supplemented with mechanical thermometers for manual reading.

For laboratory use electronic thermometers make up an increasing part of the market in Denmark (Lassen and Maag 2006). Thermometers with different probes are marketed for use in different media, and electronic thermometers for measurements at 0.1°C resolution are available.

Platinum resistance thermometers are widely used for monitoring the temperature of foodstuffs during transport (see example below). These thermometers are e.g. approved by Det Norske Veritas (DNV), Germanischer Lloyd (GL) and Lloyd's Register of Shipping (LRS) (KP 2007).

The price of platinum resistance machine thermometers is on the order of 10 times the price of a simple mercury-in-glass machine thermometer (Lassen and Maag 2006). However, price comparisons are complicated by the fact that the electronic thermometers typically consist of two separate parts: a probe (sensor) and a data logger. Several different probes may be used for the same data logger.

An electronic thermometer for use in the laboratory is marketed at a price of about ten times the price of an ordinary mercury thermometer for the same use, which would cost approximately DKK 100, or €13 (Thoft 2006). The price of a tested and certified mercury thermometer, however, is approximately DKK 1,200 – similar to the price of the electronic thermometer.

The available electronic thermometers are generally more accurate than mercury-containing thermometers, if properly calibrated, which has to be done more often than with mercury thermometers. The laboratories accredited for calibration of thermometers in Denmark typically use platinum resistance thermometers for calibrating other thermometers. The electronic thermometers are typically tested and calibrated every year, whereas mercury thermometers are typically tested every second year.

The application of electronic thermometers as alternatives to ASTM liquid-in-glass thermometers has been reviewed by Ripple and Strouse (2005). Replacing a liquid-in-glass thermometer with an electronic thermometer when applying a standard is not straightforward, but the paper suggests some guidelines for the specification and application of alternatives. The replacement is not only a question of the technical properties of the thermometers, but also of the interaction between the thermometer and the test medium (the depth and size of the sensing tip, response time, etc.). The authors concluded that the approach outlined allows the replacement of a liquid-in-glass thermometer with an alternative, offering a high degree of confidence that the replacement replicates the performance of the liquid-in-glass thermometer in all important respects.

Infrared thermometers
An infrared thermometer is a non-contact temperature measurement device. Infrared thermometers allow users to measure temperature in applications where conventional sensors cannot be employed. They are not directly comparable to mercury-in-glass thermometers. Infrared thermometers appear to have replaced mercury pyrometers.

Level of substitution and mercury consumption in thermometers
- Liquid-in-glass thermometers for non-medical uses
For most industrial applications electronic thermometers are replacing mercury thermometers due to the advantages of automatic reading. In laboratories and for some very specific applica-

tions in industry, however, mercury thermometers are still widely used. Some standards, e.g. some DIN standards (Germany), the PI standards (UK) and ASTM (USA but widely used in Europe as well) prescribe the use of mercury thermometers, which may be a barrier to phasing out mercury thermometers for laboratory use. This issue is further discussed in the impact assessment of policy options in section 6.5.

According to a Swedish policy paper, alternative techniques exist for most measurements and it seems as though mercury thermometers in equipment have gradually been replaced by newer techniques in Sweden (Kemi 2004). The consumption of mercury in thermometers in Sweden decreased during the period from 1991/92 to 2003 from 328 kg/year to 0.07 kg/year (Kemi 2004). In Denmark mercury thermometers are now only allowed for calibration and laboratory use.

One specific use of mercury thermometers with no current alternatives is in flash-point determination (Kemi 2004). This type of measurement is used in the oil industry and by companies providing analytical services. Flash-point measurement is regulated by Directive 67/548/EEC, which indirectly requires mercury thermometers to be used. Therefore these thermometers have an exemption from the current Swedish ban (Kemi 2004).

The Norwegian EPA has reported in its assessment of the consequences of a general ban on mercury in products that for measurements in autoclaves as well, the use of electronic thermometers is hindered by high pressures and temperatures (SFT 2006). Further, many laboratories must periodically test their thermometers against a calibration thermometer. Electronic calibration thermometers exist, but they are quite expensive (SFT 2006).

According to a UK manufacturer, mercury retort thermometers are considered by many users to be more reliable than electronic equipment in harsh environments (heat and steam) e.g. in the canning industry (Russell 2005).

For some applications in laboratories the mercury-in-glass thermometers have the advantage of high resistance to acids, lye and other chemicals, and the advantage of functioning without an energy source (Amarell 2005). According to the manufacturer S. Brannan & Sons Ltd. (2005), there is no adequate alternative to mercury in precision thermometers and other specialised glass instruments used in the petrochemical industry or used as temperature standards, whereas alternatives are suitable for other applications. For these reasons the mercury-in-glass thermometers are still widely used for precision temperature measurements in laboratories and industry in countries where they are not banned.

A leading manufacturer of thermometers in the UK estimated in its response to the Commission's Stakeholder Consultation in 2005 that glass thermometers account for about 20% of EU mercury consumption in measuring equipment, corresponding to about 5 tonnes mercury/year (Brannan 2005). A German producer agreed that the EU total for mercury in glass thermometers was far below 10 tonnes (Amarell 2005). Three German manufacturers consulted as part of this study estimated the EU-wide use of mercury for thermometer production today at less than one tonne per year.

As regards mercury-in-glass thermometers for laboratories and the industry, it appears that European manufacturers dominate the market. Eleven mercury thermometer manufacturers have been identified in the UK, France, Germany, Italy, Czech Republic and Romania. Specific data obtained from five manufacturers indicate annual mercury consumption in the 100-200 kg range for each.

France has reported (questionnaire response) mercury consumption in 2007 of 0.3 tonne in 20,000 non-fever thermometers.

Based on information obtained from a number of thermometer manufacturers, it is estimated that the current use of mercury for manufacturing of mercury-in-glass thermometers used in laboratories and for special purposes in industry is on the order of 1.0-1.5 tonnes per year. A small part of this is mercury thermometers inside hydrometers. One major manufacturer estimated that hydrometers may represent some 3.5% of the total mercury.

About half of the thermometers manufactured in the EU are exported. It is estimated that imported thermometers for this purpose are significantly lower than exports, and the consumption in the EU with products is estimated at 0.6-1.2 tonnes for 2007. Based on information from manufacturers it is estimated that approximately half of the mercury is used in thermometers for laboratory use, and the other half is used for industrial and marine applications.

- Other mercury thermometers used in industry

Concerning dial thermometers used in industry and marine applications, a UK thermometer manufacturer stated for the Stakeholder Consultation that a large number of products still containing mercury were not glass thermometers (many older dial-type thermometers use larger volumes of mercury per thermometer), and that such products do not need to use mercury as an actuating medium as adequate alternatives and technologies already exist (Brannan 2005). Mercury-in-steel dial thermometers are produced by at least two European manufacturers, and both have confirmed a very limited market for these thermometers because alternatives have taken over. On this basis the mercury consumption with these thermometers is roughly estimated at 0.1-0.3 tonne mercury per year.

- Medical thermometers

As mercury use in medical thermometers is now banned in the EU, limited resources have been devoted to investigating the present use of mercury with medical thermometers. The market seems to have been dominated by imported products, and the mercury consumption has decreased steeply in recent years. The European umbrella organisation for manufacturers and suppliers of medical equipment, Eucomed, has stated that it does not compile data on this market.

Only a few Member States have provided information on the actual mercury consumption with medical thermometers. In Romania mercury consumption is estimated at 0.08 tonnes/year in 2004 and 2005 and 0.27 tonnes in 2006 (Romania questionnaire response). In the Czech Republic hospitals bought 110,000 medical thermometers in 2003 and a further 185,000 were imported into the country, corresponding to a total of about 0.3 tonnes mercury (Czech Republic stakeholder response 2005). The UK reported that mercury thermometers purchased each year continue to decline, and in England the number of mercury thermometers purchased for the health care sector were 15,000 for the year ending March 2005 (UK stakeholder response 2005), corresponding to about 15 kg mercury. For comparison, purchases for the year ending March 2002 were 79,000. Consumption of thermometers by private households was not indicated, but in 2002 the total amount of mercury accumulated in domestic mercury thermometers was about twice the amount accumulated in the health care sector (UK stakeholder response 2005). In Hungary mercury thermometers still dominate the medical thermometer market (Hungary questionnaire response). In the Nordic countries mercury fever thermometers have been more or less phased out for a number of years. France (questionnaire response) reported that mercury fever thermometers have been banned since 1998.

The available data indicate that the new Member States may account for a major part of the EU-wide consumption of mercury in medical thermometers. Based on this data, total mercury consumption with medical thermometers in 2007 is estimated at 1-3 tonnes.

2.5.1.2 Manometers

Manometers measure the difference in gas pressure between the measured environment and a reference. Mercury manometers are most often mercury-containing U-shaped glass or plastic tubes. The difference in the levels of mercury in each side of the tube indicates the pressure of the gas being measured. Other designs are also available, e.g. slack tube manometers and well-type manometers.

U-tube manometers are used for measuring relatively low pressures. The tubes may be filled with water, alcohol or mercury. It is reported that in Denmark U-tube manometers with water are today marketed by one company only, and used mainly in the heating and ventilation (HVAC) sector, e.g. for differential pressure measurements when adjusting oil burners in single-family houses (Lassen and Maag 2006). The mercury-filled U-tubes were used for similar purposes in the mid-1990s when measuring at higher pressure (but still at relatively low pressures compared to the range of pressures found in industry) (Lassen and Maag 2006). The filled volume varies, but it was estimated that each manometer was filled with 70-140 g mercury.

Mercury manometers are produced in Europe for laboratory use and for industrial applications. Mercury manometers marketed as laboratory-grade precision primary standard manometers are produced e.g. by Chell Instruments Ltd, UK.

Alternatives
A number of different pressure-measuring instruments are marketed, among these:

- Bourdon tube manometers;
- Electronic manometers (or digital manometers);
- Pressure gauges with diaphragm elements.

Bourdon tube manometers
The bourdon tube manometer is a circular-shaped tube with an oval cross-section. Bourdon tube manometers are today sold for applications where U-tube manometers with mercury were previously used (Lassen and Maag 2006). According to a Danish study, the market prices of alternatives are typically lower than the price of the mercury manometer (Lassen and Maag 2006).

Electronic (or digital) manometers
Electronic manometers measure the pressure by use of pressure transducers, e.g. piezoelectric pressure transducers or capacitance pressure transducers, which are connected via an analogue-to-digital converter to a display or data logger. Electronic manometers are widely used in industry as they can be used for automatic and remote control.

The price of electronic manometers is estimated to be about 3-4 times the price of a mercury manometer for similar pressure range (Lassen and Maag 2006), but the electronic manometers have the advantage of automatic measurements and for this reason cannot be directly compared to mercury manometers. According to Gallican *et al.* (2003), a digital manometer can also be more precise than a mercury manometer if properly calibrated.

Small hand-held manometers that serve a similar purpose as mercury manometers, e.g. for applications within the heating and ventilation sector, are sold by many suppliers. The price of the hand-held manometer is approximately 4 times the typical price of a mercury U-tube manometer (Lassen and Maag 2006).

Laboratories calibrating manometers may still use mercury manometers as reference instruments, but mercury-containing reference instruments are being replaced by electronic instruments. For example, the last mercury reference instrument used by the reference laboratory of the Danish Technological Institute was replaced in June 2006 by electronic equipment (Lassen and Maag 2006).

A special type of pressure measurement is required in the polyethylene manufacturing industry where a precision measurement is made at high temperature (Kemi 2004). The polyethylene product is evaluated by this pressure measurement, which is an important quality-assurance parameter. Alternatives to mercury manometers have been tested over many years but none has given the required result (Kemi 2004).

On the contrary, according to a European manufacturer of mercury manometers, there is no application for which mercury manometers cannot be replaced by other devices (Giussani 2008).

Mercury consumption with manometers

Only one manufacturer in the EU has been identified, who supposed that most manufacturers in Europe have switched to making mercury-free manometers in recent years (Giussani 2008). Several suppliers identified via the internet offer manometers from the US manufacturer Dwyer. These manometers are typically sold without mercury, and the customers fill them with mercury before use.

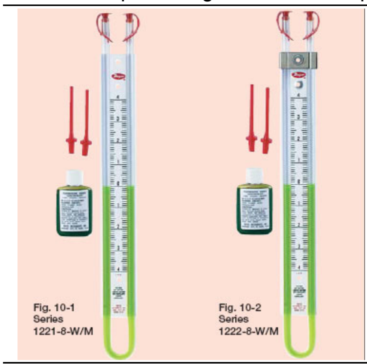
It has not been possible to obtain an estimate of the current use of mercury for new manometers, which seems to be very low. Some mercury is probably also used for maintenance of old manometers. In the 1990s in Denmark, before the Danish ban, mercury consumption was estimated at 4-8 kg per year (Lassen and Maag 2006). It is roughly estimated that the total EU consumption of mercury for filling new manometers is on the order of 0.03-0.30 tonne.

EXAMPLE:

"Manometers with a liquid column are direct pressure and vacuum gauges suitable for use in measuring laboratory or for production control systems. Built-in version as well as wall or bench version are available."

Manufacturer: Giussani srl, Italy

Source: http://www.giussanionline.it/pressure-gauges.htm



Dwyer Flex-Tube® U-Tube Manometers for HVAC applications

Manufacturer: Dwyer Instruments Inc. U.S.A.

Supplier: Hans Buck A/S, Albertslund, Denmark

Source: http://www.hansbuch.dk/files/datablad_cat_502.pdf

2.5.1.3 Barometers

A typical mercury barometer consists of a one-metre glass tube filled with mercury. One end of the tube is sealed while the other end of the tube is submerged in a container filled with mercury. The changes in the height of the mercury column (and, hence, atmospheric pressure) are measured on a scale attached to the mercury column. A barometer for private households typically contains 60-75 g mercury, whereas large barometers for laboratory use may contain up to 1.1 kg of mercury.

Barometers are used for a number of professional applications including weather stations, meteorological departments, airports and airfields, wind tunnels, oil refineries, engine manufacturing, sporting sites, offshore installations (e.g. windmill parks) and on ships.

Barometers are produced by a number of manufacturers in the EU, of which six are listed in section 2.5.5. Very few are producing barometers for the professional market. Barometers manufactured in the EU are commonly exported outside the EU, especially for professional applications.

Alternatives
A number of alternative barometers are marketed, among these:

- Electronic barometers (e.g. aneroid displacement transducers, digital piezo-resistive barometers or cylindrical resonator barometers);
- Electronic resistance or capacitance barometers;
- Aneroid mechanical barometers;
- Mercury-free liquid barometers.

Electronic barometers
Most barometers of recent design make use of transducers which transform the sensor response into a pressure-related electrical quantity in the form of either analogue or digital signals (WMO 2006). For professional use, electronic barometers for automatic data logging appear to represent the main market today, whereas aneroid ("aneroid" = "liquid-free") barometers may still be used for applications in households.

A cylindrical resonator barometer (or vibrating cylinder air-pressure transducer) is designed to measure absolute air pressure using the vibrating element principle, providing a frequency output from which pressure is computed. Accurate barometers, e.g. for calibration of other barometers at the Danish Meteorological Institute, are based on the vibrating cylinder air-pressure transducer principle (Lassen and Maag 2006). According to a manufacturer of mercury barometers for the professional market, electronic barometers can replace mercury for all applications. Precise and stable digital instruments with quartz Bourdon tubes are used as working standard reference barometers in calibration laboratories (WMO 2006).

A widely applied type of electronic barometer, the aneroid displacement transducer, contains a sensor with electrical properties (resistance or capacitance) that changes as the atmospheric pressure changes. In Denmark these barometers are today used by weather stations, ships, airports, etc. (Lassen and Maag 2006).

Aneroid mechanical barometer
The mechanical aneroid barometer is more compact than the mercury barometer and consists of an evacuated metal diaphragm linked mechanically to an indicating needle. Aneroid barometers have been used for approximately 200 years and are considered just as accurate as the traditional mercury barometer (Gallican *et al.* 2003).

Mercury-free liquid barometers
A mercury-free liquid barometer, with a U-shaped glass tube filled with a red silicone fluid and gas, is produced by the Belgian manufacturer Dingens Barometer. These barometers are marketed for use in schools and hospitals. The Eco-celli barometer costs one-third to one-half less than a comparable mercury barometer (Dingens 2008).

Level of substitution

According to the World Meteorological Organisation (WMO 2006) there is an increasing move away from the use of mercury barometers for many reasons, and alternatives with electronic read-out and with equivalent accuracy and stability are now commonly available.

Mercury barometers are widely used in private households, however, and by most users they are considered a piece of furniture. A major UK supplier has estimated the total mercury content of modern domestic barometers supplied for private customers in the UK today at <20 kg per year. Assuming new domestic barometers contain approximately 60 g mercury, that is equivalent to less than 300 barometers per annum (Collin 2008). Until the ban enters into force in 2009, mercury barometers for private households will continue to be manufactured by several producers in the EU.

The total mercury content of barometers supplied from the UK to the professional market outside the EU is <40 kg mercury per year. The UK professional market is estimated at <10 kg mercury per year (Collin 2008). The customers/users are scientific, medical and special test laboratories, airfields as well as some educational institutions. Some scientific mercury barometers are used for calibration of other barometers, e.g. aneroid and electronic types. Today Russell Scientific is the only EU manufacturer of Fortin and Kew type mercury barometers for the professional market (Collin 2008).

France (questionnaire response) estimated on the basis of information from an industry association that 20,000 barometers with a total content of 1.5 tonnes mercury (75 g per barometer) were sold in France in 2007. The per capita consumption in France is consequently implied to be far higher than the per capita consumption in the UK. No data was received from other countries so there is no basis for determining which, if either, country may be representative of the EU.

Overall, at EU level the total mercury consumption in barometers has been estimated at 2-5 tonnes, of which the professional market in the EU represents about 0.1-0.5 tonne.

EXAMPLE:

"*Direct reading barometer with silvered metal scale mounted on a polished hardwood board with spirit thermometer and separate °F and °C scales. Nominal bore of mercury column is 2mm. Normal range is 780/1060 mb (h Pa) or 585/790mm Hg.*"

Manufacturer: Russell Scientific Instruments Ltd., U.K.

http://www.russell-scientific.co.uk/products/73_direct_reading_barometer.html

2.5.1.4 Blood pressure measuring devices – sphygmomanometers

A mercury sphygmomanometer (from Greek *"sphygmos"* for pulsation) includes a mercury manometer, an upper arm cuff, a hand inflation bulb with a pressure control valve and requires the use of a stethoscope. The method relies on the auscultatory technique, in which a clinician determines systolic and diastolic blood pressures (SBP and DBP) by listening (auscultate) for sounds that characterize different stages of blood flow during cuff deflation (so-called Korotkoff sounds). The accuracy of blood pressure measurement using the mercury sphygmomanometer relies heavily on taking multiple readings, having a relaxed patient (who has been sitting for at least several minutes before measurements are taken), and perhaps most importantly, a competent clinician (Watson and Lip 2006). The latter needs to be able to select an appropriate-sized cuff (80% of the upper arm circumference), as well as be able to deflate the cuff at a relatively slow but continuous rate (2–3 mm Hg/sec.) and accurately auscultate and discriminate between the Korotkoff sounds to provide a reproducible reading.

Mercury sphygmomanometers have been used for more than 100 years and are still considered by many to be the "gold standard" of blood pressure measurements. Mercury sphygmomanometers manufactured in the EU typically contain 85 to 100 g mercury.

EXAMPLE:

"*0022 Accoson Freestyle Mercury Sphygmomanometer Desk Model*

Made in UK and guaranteed accurate to BS EN 1060-1"

Manufacturer: AC Cossor & Son (Surgical) Ltd

Source: http://www.oncallmedicalsupplies.com

Alternatives
Alternatives to mercury-containing sphygmomanometers on the market can roughly be divided into the following groups:

- Equipment for blood pressure measurements based on the auscultatory technique
  - Aneroid sphygmomanometers for manual reading;
  - Digital sphygmomanometers for manual reading;

- Equipment for blood pressure measurements based on the oscillometric technique or other techniques
  - Semiautomatic devices for clinical use and home/self assessment;
  - Automatic blood pressure devices for hospital use.

Annex 3 includes an overview table of blood pressure measurement devices reviewed by the UK Department of Health, Medicines and Healthcare Products Regulatory Agency (MHRA) (MHRA 2006). The list includes indicative prices of the equipment on the UK market that supplement the prices on the Danish market indicated below.

Equipment based on the auscultatory technique
The manual aneroid sphygmomanometer works in a similar way to the mercury sphygmomanometer, but an aneroid (liquid free, from Greek *a*= without + *nēros* = liquid) gauge replaces the mercury manometer. The accuracy of the measurements rely on the same properties as mentioned for mercury sphygmomanometers, but in addition the question arises about the reliability of the aneroid manometer as compared to the mercury manometer.

Several traditional type aneroid mechanical sphygmomanometers have been validated for clinical use, meeting the criteria of the BHS protocol of the British Hypertension Society (BHS 2008). A list of validated aneroid sphygmomanometers for clinical use can also be found on the dabl® Educational Trust website on blood pressure measurements (Dabl 2008). The dabl website provides as overview of the results of validation tests by AAMI (Association for the Advancement of Medical Instrumentation), BHS (British Hypertension Society) and ESH (European Society of Hypertension). The most recent guidelines from the Task Force for the Management of Arterial Hypertension of the European Society for Hypertension (ESH) and of the European Society of Cardiology (ESC) specify that mercury-free devices can be used and will become increasingly important because of the progressive banning of the medical use of mercury, but they should be validated according to standardised protocols (with reference to the dabl website) and the equipment should be checked periodically by comparison with mercury sphygmomanometric values (ESH/ESC 2007). The dabl website lists 5 manual mercury-free devices that pass the test of the ESC.

One drawback of aneroid manometers has traditionally been that they were susceptible to shock. Different designs are available today, and the manufacturer Welch Allyn (USA) has introduced a new concept (DuraShock) for an aneroid sphygmomanometer that is more shock-resistant than a conventional aneroid sphygmomanometer (Galligan *et al.* 2003). Similarly, the German producer Riester introduce in the second half of 2008 a shock-resistant aneroid sphygmomanometer, Focus Green (Riester 2008). The sphygmomanometer is specified to be shock-proof to a drop of up to 120 cm. Both manufacturers specify that their sphygmomanometers are not susceptible to shock and provide the equipment with a 5-year calibration warranty.

A new type of aneroid sphygmomanometer marketed as an alternative to mercury sphygmomanometers, e.g. as a reference manometer, combines an electronic manometer with a dial for manual reading. The device, manufactured by A.C. Cossor & Son (Surgical) Ltd in the UK, carries out an auto-calibration to zero each time it is switched on, and meets the criteria of the International Protocol for blood pressure measuring devices in adults (BHS 2008). The sphygmomanometer is sold to general medical practitioners for use as a reference instrument and for clinical use. The U.S. producer Welch Allyn also provides sphygmomanometers with electronic manometers in the Maxistabil series.

Blood pressure measurements based on other methods than oscillometry are needed for some specific clinical conditions including arrhythmia, pre-eclampsia and certain vascular diseases (IAG 2005). The UK Independent Advisory Group on Blood Pressure Monitoring in Clinical Practice recommends that calibrated mercury-free devices, which do not rely on oscillometry, should be made available in all clinical areas. These should be used to check oscillometric results and other non-auscultatory alternative blood pressure measurements on individual patients. Where aneroid gauges are used for sphygmomanometry, their calibration accuracy should be regularly checked based on the manufacturer's recommendation, or annually (IAG 2005).

A Swedish investigation summarized the Swedish health care sector experience in phasing out mercury sphygmomanometers as follows: "*There were only positive experiences reported from the phase-out of mercury in the most widespread equipment called sphygmomanometers, which today is complete*" (Kemi & Miljø Konsulenterne 2005). It was further concluded, "*There are no problems in diagnosing any condition using non-mercury sphygmomanometers including in the presence of arrhythmia, preeclampsia and in accelerated (malign) hypertension.*" … "*There is no evidence that the need for checks and calibrations cause practical problems or diagnostic problems. There are no reports of problems or inconveniences related to the change in routines.*"

The manual aneroid and digital sphygmomanometers are widely sold in the Member States for applications by general medical practitioners and in hospitals, which comprise the main market for sphygmomanometers today. The evaluation of MHRA (MHRA 2006) noted that the decreasing cost of automated devices, together with the improved reliability of the aneroid devices and the introduction of manual electronic sphygmomanometers, are leading to a further reduction in the use of mercury sphygmomanometers.

The prices in Denmark for BHS validated devices range from about the same, to twice the price of mercury sphygmomanometers; the highest price being for the electronic/manual reference sphygmomanometers. The price of a Europe-made mercury sphygmomanometer is approximately DKK 1,000 excl. VAT, or €133 excl. VAT.

In Germany, with a highly competitive market for sphygmomanometers, the price of a German-made sphygmomanometer is approximately €60 (excl. VAT) for a general practitioner. The market price of aneroid sphygmomanometers from the same manufacturer is about €50, and the shock-resistant aneroid sphygmomanometer introduced this autumn is expected to be sold at a price slightly above the price of the conventional aneroid sphygmomanometer.

Prices of different models from the same manufacturer have been obtained from the UK market. Desk models of Accoson sphygmomanometers can be purchased in the UK on the internet at the following prices (excl. VAT): Mercury sphygmomanometers about £50 (€63), conventional aneroid sphygmomanometers at the same price, Greenlight 300 sphygmomanometers at about £130 (€165). The Welch Allyn Maxistabil desk models are available at £70 - 170 (€89-215), depending on the model, whereas the Welch Allyn DuraShock is available at about the same price as the mercury sphygmomanometer.

Cheap “unbranded” mercury sphygmomanometers can be purchased on the internet at prices down to €10-15, but these products are not considered to be viable alternatives to those discussed above.

For the cost estimates used in section 6.5 it is assumed that the prices of the mercury sphygmomanometer and the shock-resistant aneroid sphygmomanometer are about €60, whereas the price of a sphygmomanometer with an electronic manometer that can be used for calibration of other equipment is about €160.

Equipment based on the oscillometric technique or other techniques
Semi-automatic electronic blood pressure devices have undergone extensive development during recent years, and a large number of different devices are marketed today. They typically use the oscillometric technique and include an electronic monitor with a pressure sensor, a digital display, an upper arm cuff and a hand-operated inflation bulb.

The semiautomatic electronic devices are today standard for home/self assessment in many countries and are also widely used by general medical practitioners. The European Society of Hypertension states that for self assessment, electronic devices using oscillometry are becoming more popular and are replacing the auscultatory technique. The electronic devices require less training and are more suitable for patients with infirmities such as arthritis and deafness.

Equipment meeting the criteria of the BHS protocol of the British Hypertension Society is available at approximately the same price as that of a mercury sphygmomanometer.

For automatic measurements in hospitals, more advanced equipment, which often combines the measurements of blood pressure with monitoring of temperature, heart rate and blood oxygen level, are applied. The majority of the devices currently available use the oscillatory method (MHRA 2006)

The European Society of Hypertension Working Group on Blood Pressure Monitoring has stated, with regard to automated devices as alternatives to mercury sphygmomanometers, that an accurate automated sphygmomanometer capable of providing printouts of systolic and diastolic blood pressure, together with heart rate and the time and date of measurement, should eliminate errors of interpretation, should abolish observer bias and terminal digit preference, and should be used whenever possible (ESHWG 2005).

In spite of the accuracy of the manometer, blood pressure measurements with manual equipment are not necessarily reproducible because many other factors influence the measurements. In the most recent guidelines on diagnostic blood pressure measurements, the Danish Hypertension Society concluded that it is now documented that both 24-hour measurements and blood pressure measurements at home are more reproducible and predict cardiovascular events more precisely than blood pressure measurements in the clinic (Bang *et al.* 2006).

The price of this equipment is typically on the order of 10 times the price of a mercury sphygmomanometer (Lassen and Maag 2006), but these advanced devices cannot be directly compared to mercury sphygmomanometers, as they have many more features.

Level of substitution

The advantages and drawbacks of mercury sphygmomanometers have been intensively discussed in the medical literature. Compared to other measuring devices, the main advantages of mercury sphygmomanometers are that a mercury manometer is relatively easy to use by people who are trained in reading the meter, it is stable, and it is easy to see whether it functions properly. It is still considered the “gold standard” for blood pressure measurements (see also Annex 3).

The main drawback of mercury sphygmomanometers, and the main reason for their phase-out in the hospital and in other sectors, is that they are not suitable for automatic measurements. Further, hazardous mercury may be spread to the surroundings by breakage of the manometer.

As indicated in Annex 1, the level of substitution ranges among countries. In Sweden and Lithuania “Mercury use is fully, or almost fully, substituted,” whereas in the UK “Alternatives are commercially mature and have significant market shares, but do not dominate the market.” The latter information regarding the UK market is not consistent with the latest information from a major manufacturer suggesting that mercury sphygmomanometers today comprise about 10% of the market for manual sphygmomanometers, and are sold almost entirely to general practitioners.

Mercury use with sphygmomanometers

The European trade organisation EUCOMED has claimed that the organisation does not have information on the current use of sphygmomanometers across the EU.

In the UK the sale of sphygmomanometers fell from about 2,800 units in 2003 to about 1,800 units in 2006 containing a total of 0.15 tonne mercury (85 g mercury on average) and representing about 10% of the sphygmomanometer market. If these volumes are extrapolated on a per capita basis, the EU-wide consumption would be about 1.2 tonnes.

It is estimated that mercury sphygmomanometers account for 5-15% of the blood pressure measuring equipment sold in Denmark in 2006, and the total mercury content is estimated at 12-28 kg Hg/year (Lassen and Maag 2006). If the volumes are extrapolated on a per capita basis the EU-wide consumption would be 1.1-2.6 tonnes mercury.

The total number of sphygmomanometers in use in Hungary is 29,000 (Hungary, questionnaire answer) which corresponds to approximately 2.0-2.5 tonnes mercury. No data on current sales is available.

A German manufacturer estimated the EU-wide market for sphygmomanometers at about 60,000 units (about 5-6 tonnes Hg), with the Italian and Eastern European markets as the major ones, supplied mostly by imported products. In Italy and Eastern Europe the mercury sphygmomanometer makes up a significant part of the market, whereas in other parts of the EU it makes up about 10% or less.

Considering the available data, total EU-wide annual mercury consumption in sphygmomanometers is estimated at 3-6 tonnes in 30,000 - 60,000 units. The sphygmomanometers are sold mainly to general practitioners. Mercury sphygmomanometers are not purchased by hospitals in the countries for which information has been provided (UK, Germany, Denmark and Sweden) and the same is assumed to be true for most other Western European Member States.

Four manufacturers of mercury sphygmomanometers in the EU have been identified, but it cannot be excluded that a few additional manufacturers may be present in the EU. All four identified manufacturers also produce mercury-free sphygmomanometers. Several brands of mercury sphygmomanometers are imported from non-EU countries including Japan, USA and China. Imports account for the majority of the EU market, but in the UK and Germany (and maybe others) domestically produced sphygmomanometers dominate the market.

There is a significant export of mercury sphygmomanometers manufactured within the EU to countries outside the EU. European-made sphygmomanometers are in demand because they are considered to be of higher quality by customers, and are more resistant to breakage and release of mercury. Based on available information, it is estimated that annual exports comprise at least 60,000-90,000 units corresponding to 5-8 tonnes mercury.

2.5.1.5 Blood pressure measuring devices – strain gauges

Mercury strain gauges are used for blood flow and blood pressure measurements in body parts using a technique called strain gauge plethysmography (from the Greek *"plethysmos"* for increase: measuring how limbs change in size at different pressures). The mercury strain gauge consists of a fine rubber tube filled with mercury which is placed around the body part in which the blood pressure or blood flow is measured. The method is used for diagnosing certain kinds of arteriosclerosis, a chronic disease in which thickening, hardening, and loss of elasticity of the arterial walls result in impaired blood circulation. Kemi & Miljø Konsulenterne AB (2005) estimated that no more than 200 strain gauge tubes are needed annually for the whole of Sweden. According to the Newmoa Mercury Added Database, D. E. Hokanson Inc, one major global producer of strain gauges consumed 946 grams mercury in 2004 for production of strain gauges (Newmoa 2007). This indicates that the total EU consumption for this application may be insignificant in comparison with the amount of mercury used in sphygmomanometers.

EXAMPLE:

"*Hokanson strain gauges are available in Mercury or Indium-Gallium types. They can be ordered in sets or individual sizes.*"

Manufacturer: D. E. Hokanson, Inc., USA

Supplier: P.M.S (Instruments) Ltd, UK.

Source: http://www.pmsinstruments.co.uk/Strain%20Gauges.htm

Alternatives

Available alternatives to mercury-containing strain gauges for plethysmography can be divided into the following groups:

- Strain gauges with indium-gallium;
- Photo cell or laser-Doppler techniques.

Alternatives to mercury stain gauges has recently been evaluated in the Swedish study (Kemi & Miljø Konsulenterne AB 2005) and the following information is mainly based in this study.

Indium-gallium strain gauges
Indium-gallium strain gauges are marketed for purposes similar to the mercury strain gauges (see illustration above).

Photo cell or laser-Doppler techniques
The Doppler technique uses the Doppler effect to measure the velocity of red blood cells to determine blood flow at different pressure conditions. There are ultrasonic Doppler devices for big vessels, or laser Doppler devices for small measurement volumes. The photo cell technique registers changes in tissue colour at different pressure conditions. The Doppler and photo cell techniques are typically used for measurements in fingers and toes.

Level of substitution
According to the Swedish study, mercury equipment is now being successfully replaced by equipment using photo cell or laser-Doppler techniques. At the clinics these techniques and the gallium/indium strain gauges can satisfy all required kinds of diagnosis that were previously served by mercury-containing equipment.

The reason why equipment containing mercury is still in use in Sweden is mainly not medical but economic The mercury-containing tube is not very expensive and has a life span of around one year. But the tube is developed to function together with complex electronic measuring equipment that costs more than EUR 20,000 and has a life span of 10-15 years. The mercury-free products are fully competitive with mercury equipment on a price basis and on functionality, but clinics hesitate to invest in a new system unless the existing system breaks down.

In some cases mercury-containing equipment is still in use at specialist clinics and contributes to the diagnosis and monitoring of certain kinds of arteriosclerosis. The number of patients that depend on the use of mercury strain gauge techniques is not known but it is estimated that no more than 200 strain gauge tubes are used annually in Sweden.

Mercury strain gauge plethysmographs are mostly used for research purposes. There is at present no alternative to mercury-containing plethysmographs in research where absolute blood flow in arms and legs is examined. That is because of the huge body of reference material that has been built up during decades of use. Kemi & Miljø Konsulenterne AB (2005) estimated in 2005 that within 4-5 years mercury-free plethysmographic equipment will be validated for all areas where strain gauges are used – clinical as well as research use. There is apparently no technical obstacle to using mercury-free techniques for all areas of use once the proper validation is in place.

2.5.1.6 Hygrometers

Hygrometers (or psychrometers) are used in the measurement of relative humidity. They consist of two (often mercury) thermometers mounted together, one of which has a cloth wick over its bulb and is called a wet-bulb thermometer. When a reading is to be taken, the wick is first dipped in water and then the instrument is whirled around. During the whirling, the water evaporates from the wick, cooling the wet-bulb thermometer. The temperature difference provides the basis for calculating the relative humidity.

EXAMPLE:

"*Plastic-cased wet and dry bulb hygrometer suitable for indoor or outdoor use with mercury filling. Uses a simple chart calculator for readings. Accuracy is to within 5% RH.*"

Manufacturer: Russell Scientific Instruments Ltd., U.K.

Source: http://www.russell-scientific.co.uk/products/43_masons_hygrometer.html

Alternatives

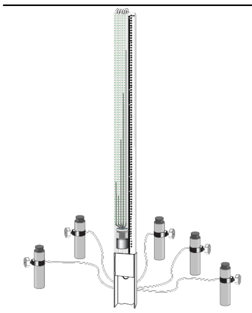
Alternatives to mercury hygrometers are spirit-filled hygrometers and electronic hygrometers. The price of spirit-filled hygrometers is approximately the same as the price of mercury hygrometers (Gallican *et al.* 2003). Electronic hygrometers are widely available,

Mercury consumption

Four EU manufacturers of hygrometers have been identified. No specific information on the total mercury content of hygrometers marketed in the EU has been identified, but the total amount is considered to be much lover than the total mercury consumption with thermometers or barometers. On this basis EU-wide mercury consumption in hygrometers is estimated at 0.01-0.1 tonne per year.

2.5.1.7 Tensiometers

Tensiometers are used to determine the level of soil moisture tension (soil water potential). The tensiometer consists of a ceramic sensor and a manometer for reading. In the case of a mercury tensiometer, the manometer consists of a mercury column similar to that of a mercury manometer. The mercury content may be up to 0.5 kg. Mercury tensiometers are mainly used for research applications.



EXAMPLE:

"*Known as the best method to measure water potentials in soils, the tensiometer has become an easy to use and very handy tool for field research in agronomy & agriculture. The STM 2150 is based on the mercury manometer principle and is at the same time very cheap and robust.*"

Manufacturer: SDEC France, France

Source: http://www.sdec-france.com/produits.php?numprod=1&lg=an

EXAMPLE:

"*T-2100 MERCURY TENSIOMETER*

The Mercury Tensiometer is particularly well suited for lighter or semi-heavy soils and/or water-sensitive crops because of its extreme rapid responses to changes in water-availabilty. The Mercury Tensiometer is also very accurate and provides refined reading values."

Manufacturer: A.M.I., USA

Source: http://www.aidlltd.com/tensiometers.html#Mercury_Tensiometer

Alternatives
The manometer of the mercury tensiometer can, for all applications, be replaced by manometers of other types similar to the types described under manometers. Electronic tensiometers and tensiometers with mechanical bourdon manometers are marketed for the same purposes as the mercury tensiometers e.g. by SDEC France. The development and calibration of electronic tensiometers against mercury tensiometers are described by Teixeira and Coelho (2005).

Level of substitution
Like mercury manometers, tensiometers are shipped without mercury and are filled with mercury by the user.

In the EU only one manufacturer of mercury tensiometers has been identified, who has reported that production will be discontinued in 2008. Sales of mercury tensiometers have been in the range of 10-15 pieces per year.

On the basis of available information the annual EU-wide consumption of mercury in tensiometers is estimated to be in the range of 0.01-0.1 tonne per year.

2.5.1.8 Mercury-containing reference electrodes

Mercury-containing reference electrodes are used for a variety of measurements. A reference electrode provides a stable potential whatever the measurement conditions. The main differences between reference electrodes are the type of reference system and the liquid junction. Marketed mercury-containing reference electrodes include calomel (Hg/Hg_2Cl_2), mercurous sulphate (Hg/Hg_2SO_4) and mercuric oxide (Hg/HgO) electrodes (Radiometer Analytical 2007). The calomel electrode is widely used for pH measurements, while mercurous sulphate is used e.g. for silver halides and COD titrations. Mercury electrodes are manufactured in Europe by Radiometer Analytical, France.

Goodman and Robertson (2006) estimated in an investigation for the European Commission the total mercury use in electrodes for medical equipment at 2-10 kg/year and in monitoring and control instruments at about 3 kg/year. The total mercury use with electrodes is on this basis estimated at 0.005-0.015 tonnes.

For pH measurements and as a reference electrode, mercury-containing electrodes have mostly been replaced by electrodes based on silver/silver chloride, but they can be detrimentally affected by sulphides and can be unsuitable as a reference electrode for chemical analysis of chloride or silver concentrations (Goodman and Robertson 2006). The problem with sulphide can be overcome by the use of a suitable barrier, and commercial silver/silver chloride electrodes for use in sulphide environments are available (Goodman and Robertson 2006).

2.5.1.9 Hanging drop mercury electrodes

Hanging drop mercury electrodes are used in polarography and voltammetry. The electrodes are formed by mercury dropping regularly from a capillary tube. Contrary to the reference electrodes mentioned above, mercury has to be continuously added to the electrodes. The polarographic method is used to analyze trace elements in water, environmental samples or ultrapure chemicals. Examples of electrodes are the Hanging Drop Mercury Electrode, the Dropping Mercury Electrode (DME) and the Static Mercury Drop Electrode (SMDE) or multi-electrodes that can operate in different modes (Metrohm 2008). The typical mercury use for an instrument is on the order of 10 ml per year (136 grams) and the total annual consumption of mercury for hanging drop electrodes in Denmark is approximately 1.4 kg (Høj 2008). The use of this equipment is, however, not so widespread in Denmark as in other countries, in particular in the new Member States, so the consumption in Denmark may be significantly below the European average (Høj 2008). On that basis it is roughly estimated that the EU-wide mercury consumption for this application in 2007 was 0.1-0.5 tonne per year.

The advantage of the mercury equipment is primarily that it is cheap compared to the equipment for more advanced measuring methods. Mercury electrodes for polarography are banned in Sweden but exempted from the Norwegian ban until 31 December 2010.

2.5.1.10 Other applications

A **gyrocompass** is a compass that finds true north by using a fast-spinning wheel and friction forces in order to exploit the rotation of the Earth. Attaching a tube partially filled with mercury to the frame of the gyro assembly in such a way that the tube tilts as the gyro axle tilts, takes advantage of the effect of gravity about the horizontal axis of the gyro. In other words, the weight of the mercury on the west or low side applies a force about the horizontal axis of the gyro. In the gyrocompass the controlling forces are applied automatically in just the right direction and proportion to cause the gyro axle to seek and hold the true meridian, that is, to point north and south (Encarta 2007). In the instruction book to a gyrocompass from Kelvin Hughes Limited, UK, it is shown how to fill a syringe with 0.3 ml mercury (ca. 4 g) and pour the mercury into the bottom of the gyrosphere (Kelvin Hughes 2007). Floyd *et al.* (2002) reports the typical mercury content of a gyroscope/compass to be 15-400 g, which may have been more common in older models.

International standards for gyrocompasses are defined in ISO 8728: "Ships and marine technology — Marine gyro-compasses" and the requirements are included in "IMO Resolution A.424 (XI), Annex, Recommendation on Performance Standards for Gyro-compasses" that sets standards for gyrocompasses, but does not mention mercury.

EXAMPLE:

"*The CMZ700 gyrocompass from Kelvin Hughes provides excellent performance with three simple system configurations.*"

Manufacturer: Kelvin Hughes Limited, UK.

Source: http://www.kelvinhughes.com:8080/products_2.jsp? piture=cmz700gyro.jpg&more_info=gyro.txt&handbook=&brochure=GYRO.pdf&drawing=&cert=

Alternatives

Mercury-free gyrocompasses that are used on all types of vessels and for the same applications as mercury-containing gyrocompasses are available e.g. from the German manufacturer Raytheon Anschütz GmbH (Raytheon 2008). These gyrocompasses use a mercury-free liquid consisting of tensides and other harmless organic compounds (Denker 2008). Mercury-free alternatives seem to have been available for many years.

As regards existing gyroscopes with mercury, the mercury most probably cannot be replaced by another liquid; rather the whole gyroscope has to be replaced.

It has not been possible from contacts with manufacturers to obtain an indication of mercury use. Most probably the annual sale of gyrocompasses with mercury is on the order of several thousand and the mercury consumption for filling new gyrocompasses on the order of 0.005-

0.025 tonne. Mercury consumption for maintenance of existing gyrocompasses may be significantly higher, but no data has been provided.

Gas flow meters, used for calibration of other gas flow meters for small flows, have been reported to contain mercury in a frictionless sealing (Rasmussen 1992). The precision flow meters are held by institutions calibrating equipment and in total about ten of these meters were sold in Denmark (Rasmussen 1992). According to a study from the US (Galligan *et al.* 2003), the manufacturers contacted stated that they did not use mercury in the manufacture of new flow meters. However it was not clearly stated whether the manufacturers also make precision meters used for calibration of other meters. The application area has not been investigated further but the mercury consumption for this application is thought to be insignificant.

A **hydrometer** is a device that measures the density or specific gravity of a liquid. The hydrometer is used for many applications. From the U.S.A. it was reported that mercury may be used in hydrometers (Gallican *et al.* 2003). An internet search identified only antique mercury hydrometers with a mercury filled bulb. Some hydrometers manufactured in the EU have a mercury thermometer inside the hydrometer for simultaneous reading of the temperature, but this thermometer is no different from other thermometers, and the hydrometer is not designated as a mercury hydrometer. A major manufacturer estimates that the total EU consumption of mercury in thermometers in hydrometers today is about 24 kg. This amount is included in the estimate for thermometers. Mercury is deemed not to be used in the bulk of hydrometers in the EU today.

Coulter counters are used for automated counting and measuring the size of microscopic particles. They are widely used in the hospital sector. Mercury was previously used in Denmark in the manometers of these counters (Lassen and Maag 2006). From the U.S.A. it was reported that mercury may be present in a pressure gauge, on-off switch, timing count gauge, vacuum gauge and possibly other gauges, depending on the model (Sustainable Hospitals 2000). An example of a product marketed today is the Particle Data Elzone 180 equipped with a mercury volumetric siphon (Rankin 2008). The total mercury content of new coulter counters on the EU market is assumed to be below a few kg, if any.

Blood lead analyser. Equipment for measuring lead in blood may apply a mercury electrode. Lead in the sample is concentrated on a thin-film mercury/graphite electrode during the plating step of the analysis cycle. Instruments are manufactured by ESA Inc., USA (Evisa 2008). The total mercury content of equipment on the EU market is assumed to be below a few kg, if any.

Permeters, also known as airway controllers, are described in the literature as being used for measuring the permeability of a sand mass to a flow of air (Giordani 2000). They have been used in foundries and possibly other applications. No current uses have been identified in the EU, nor are any expected.

In **total** it is estimated that the mercury consumption in these “other applications” is in the range of 0.01-0.1 tonne.

2.5.2 Current mercury consumption and trade

The total consumption of mercury with measuring devices in 2007 in the EU27 is estimated at 7 - 17 tonnes. In terms of mercury quantities, the main applications seem to be sphygmomanometers, barometers for households, medical thermometers (mainly in new Member States), and thermometers for laboratory and industry applications. The medical thermometers and the majority of the barometers (used in households) are now banned, and the mercury consumption for these application will cease in 2009.

The mercury consumption for many of the minor applications can be estimated only with high uncertainty, but it is quite certain that the total consumption is relatively low.

Table 2-22 Mercury consumption in measuring devices in 2007

Application	Consumption Tonnes Hg/year
Medical thermometers	1 - 3
Other mercury-in-glass thermometers	0.6 - 1.2
Thermometers with dial	0.1 - 0.3
Manometers	0.03 - 0.3
Barometers	2 - 5
Sphygmomanometers	3 - 6
Hygrometers	0.01 - 0.1
Tensiometers	0.01 - 0.1
Gyrocompasses	0.005 - 0.025
Reference electrodes	0.005 - 0.015
Hanging drop electrodes	0.1 - 0.5
Other uses	0.01 - 0.1
Total (round)	7 - 17

2.5.3 Mercury accumulated in society

The mercury accumulated in society with measuring devices can be estimated on the basis of historical consumption figures and knowledge of the average lifetime of the equipment.

With reference to data from the University of Minnesota, Floyd *et al.* (2002) estimated the average lifetime of a thermometer to be 5 years, and the average lifetime of barometers, manometers and sphygmomanometers to be 10 years. Certainly some equipment will have much longer life (e.g. the same equipment is traded as antiques) but the 5-year average will be applied for thermometers and 10 years for all other equipment.

The estimated consumption of mercury in measuring equipment in 1995 (based on WS Atkins 1998), 2002 (based on Floyd *et al.* 2002) and 2007 is shown in Figure 2-5.

The total consumption of mercury in measuring equipment in 1995 has been estimated at 55 t/year based on data from the mid-1990s (WS Atkins 1998), broken down into 23 t/year for medical thermometers, and 28 t/year for other thermometers. Assuming an overall 50% reduction in the consumption figures quoted by WS Atkins in 1998, Floyd *et al.* (2002) estimated the mercury consumption in measuring equipment in the EU15+3 at about 33 t/year in 2002 with no division among application areas. For the calculations shown in Figure 2-5 it is assumed that the relative distribution between thermometers and other devices is the same as in the estimate by Atkins.

It should be noted that previous estimates of the total EU consumption of mercury have been based on quite limited data and may be quite uncertain. The indicated increase in the consumption of mercury with measuring equipment other than thermometers most probably do not reflect the actual trend in consumption.

Assuming that the accumulated amount corresponds to the total consumption of thermometers in 2003-2007 and the consumption of other measuring devices in 1996-2007, the total accumulated amount in the EU can be estimated at about 45 tonnes broken down into 13 tonnes in thermometers and 32 tonnes in other measuring devices. In particular, the estimate for thermometers, because of the steep decline in consumption, is very sensitive to the assumption regarding the average life of the equipment.

Considering available estimates from some Member States, the accumulated quantity seems to be quite low. Data on mercury accumulated in society in measuring equipment are available from the UK. In 2002, a total of 22.9 tonnes mercury was accumulated in society in measuring equipment broken down into 22.1 t/year in sphygmomanometers, 0.25 t/year in medical thermometers and 0.54 t/year in domestic thermometers (UK 2005). The estimate does not include other measuring equipment. The quantity in sphygmomanometers seems to be very high considering that mercury consumption in sphygmomanometers in 2002 was only 485 kg, whereas the amount accumulated in thermometers is lower than the consumption in 2002 as estimated by Floyd *et al.* (2002).

The stock of barometers in households in France around 2001 was estimated at 440,000 units equivalent to 4 tonnes of mercury (FNADE 2005). If the stock in other EU countries was the same per capita, the EU-wide accumulation of mercury in barometers would be 31 tonnes. Most likely the average life of barometers used in households is more than 10 years. The stock of thermometers in France in 2001 was estimated at 12 million units containing 24 tonnes mercury (FNADE 2005). The replacement rate of thermometers in hospitals was about 10% per year (FNADE 2005).

A Swedish study estimated the quantities of mercury stored in instruments and equipment in Sweden in 2003 at 15-20 tonnes (KemI 2004). The equipment also includes other applications than measuring equipment.

Considering the uncertainties in the estimates of historical mercury use in measuring devices, the fact that the estimates do not include the new Member States (except for three in the 2002 estimate) and the data from Member States indicate that the accumulated amounts may be higher than estimated on the basis of the EU-wide consumption figures, the total accumulated amount in EU27+2 is estimated at 40-100 tonnes mercury with 70 tonnes as the best estimate.

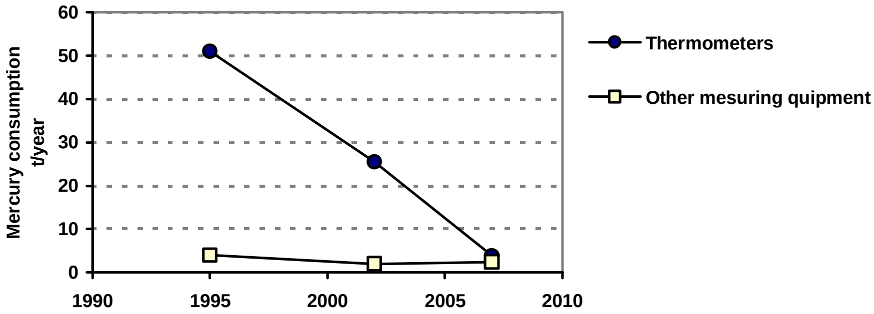


Figure 2-5 Estimated consumption of mercury in measuring equipment in 1995 (EU 15 based on WS Atkins 1998), 2002 (EU15 +3 based on Floyd et al. 2002) and 2007 (EU27+2)

2.5.4 Mercury-free alternatives

A summary of the information on alternatives to mercury-containing measuring devices is shown in Table 2-23. The background for the table is described in the previous section. It should be noted that in many cases the mercury products cannot be directly compared to the electronic devices, as the electronic devices have more features; e.g. can be used for automatic data logging or measure more parameters.

The indicated substitution level is based on information on substitution level provided by Member States (see Annex 1) supplemented by an assessment made by the authors. A range indicates that different substitution levels are reached in different Member States.

See also summary for equipment for blood pressure measuring in Annex 3.

Table 2-23 Overview of marketed alternatives to mercury-containing measuring equipment

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Fever thermometers	Liquid-in-glass thermometer	=	2-4	Banned by Directive 2007/51/EC
	Electronic thermometers	=		
Mercury-in-glass thermometers for machines, engines, boilers, etc.	Liquid-in-glass thermometer (up to 250°C) (at 1 degree)	=	3-4	Some applications in industry where mercury is difficult to substitute
	Dial thermometers (up to 650°C)	+		
	Electronic thermometers (at 0.1 degree)	++		
Mercury-in-glass thermometers for ambient air temperature measurements incl. min/max measurements	Liquid-in-glass thermometer	=	4	
	Electronic thermometers	+/++		

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Mercury dial thermometers for use in the industry and on ships	Dial thermometers with rods/capillaries with other liquid or gases	+	4	
	Electronic thermometers	++		
Mercury-in-glass glass thermometers for laboratory use	Liquid-in-glass thermometer (at 1 degree)	=	3 0 (Lithuania)	Electronic thermometers ~ same price as certified Hg thermometers Some applications in laboratories where mercury is difficult to substitute
	Liquid-in-glass thermometer with proprietary liquid (at 0.1 degree) - limited temperature range	=/+		
	Electronic thermometers (at 0.1 degree resolution at a wide temperature range)	+/++		
Mercury pyrometers for high temperature measurements	Infrared temperature sensors	N	n.a.	
	Pyrometers with nitrogen containing stem	N		
Manometers for pressure measurement in the heating and ventilation sector	Bourdon tube manometers	-/=	4	
	Electronic manometers	+		
Barometers for households	Aneroid barometers	=	2-4	Banned by Directive 2007/51/EC
	Mercury-free liquid barometers	=		
Barometers for weather stations, ships, offshore installations, etc.	Electronic resistance or capacitance barometers	N	3-4	
High-accuracy barometers, e.g. for calibration	Electronic barometer with vibrating cylinder air pressure transducers	N	3-4	
Manual blood pressure measurements	Aneroid sphygmomanometer	- /=	3-4	
	Shock resistant aneroid sphygmomanometer	=		
	Manual electronic sphygmomanometer	=		
Blood pressure measurements reference manometer for general medical practitioners	Manual electronic sphygmomanometer	+	3-4	
Blood pressure measurements in the home	Semiautomatic electronic devices	=	4	

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Automatic blood pressure measurements in hospitals	Automatic blood pressure measuring devices for monitoring of blood pressure and other vital signs	++	4	
Strain gauges	Indium-gallium strain gauges	N	3-4	For research there is still a need for more independent validations of the alternatives against the mercury gauges
	Photo cell or laser-Doppler techniques	N		
Hygrometers	Hydrometers with mercury-free thermometer Electronic hygrometers	=	3-4	
Hydrometers	Hydrometers with mercury-free thermometer	N	3-4	
Tensiometers	Electronic tensiometers	-/=	4	
	Tensiometers with mechanical bourdon manometer	+		
Hanging drop electrodes	A number of other analysis methods	++	2-3	The alternatives applies totally different methods and are not readily comparable
Mercury reference electrodes	Alternatives are not available for some specific applications	N	2-3	
Gyrocompasses	Gyrocompasses applying an organic liquid for electrical contact	=	2-3	
Coulter counters		N	n.a.	

Key assigned to the overall current user/consumer price levels for mercury-free alternatives as compared to mercury technology:
– Lower price level (the alternative is cheaper)
= About the same price level
\+ Higher price level
++ Significant higher price levels (more than 5 times higher)
N Not enough data to assign an indicator

Key to assigned substitution level indices:
0 No substitution indicated in assessed data sources; development often underway
1 Alternatives are in commercial maturation, or are present on the market but with marginal market shares
2 Alternatives are commercially matured and have significant market shares, but do not dominate the market
3 Alternatives dominate the market, but new production with mercury also have significant market shares
4 Mercury use is fully, or almost fully, substituted
N Not enough data found to assign an indicator
? Indicator very uncertain due to limited data

2.5.5 Producers of mercury-containing products

The following list of manufactures of mercury-containing measuring equipment in the EU is based on Member State responses to the questionnaire, internet search and contact to market players. The list is not considered comprehensive, but is deemed to include the major manufacturers for most product groups.

Country	Product type	Name of producer
UK	Gyrocompasses	Kelvin Hughes Limited, UK.
IT	Manometers (The manometers are added mercury by the user)	Guissani srl., Italy
FR	Mercury-containing reference electrodes, mercury hanging drop electrodes	Radiometer Analytical SAS, France
SW	Mercury drop electrodes for voltammetry and polarography (The electrodes are added mercury by the user)	Metrohm Ion Analysis, Switzerland
UK	Mercury sphygmomanometer	AC Cossor & Son (Surgical) Ltd., UK
DE	Mercury sphygmomanometer	Rudolf Riester GmbH & Co. KG, Germany
DE	Mercury sphygmomanometer	ERKA. Kallmeyer Medizintechnik GmbH & Co. KG
FR	Mercury sphygmomanometer	Spengler , France
FR	Tensiometers	SDEC France, France (production will be discontinued in 2008)
DE	Thermometers	Sika Dr Siebert und Kühn & Co. K, Germany
DE	Thermometers	Ludwig Schneider GmbH & Co. KG, Germany
DE	Thermometer	Klaus-Dieter Radschuwait, Germany
FR	Thermometers, hydrometers	ALLA FRANCE, France
FR	Thermometers, barometers, hygrometers	STIL, France
IT	Thermometers, barometers, hygrometers	Gusmini & Balconi S.R.L., Italy
UK	Thermometers	S Brannan & Sons Ltd, UK (also manufacturing site in Sweden)
RO	Thermometers	SC Termodensirom, Romania
CZ	Thermometers	Exatherm s.r.o, Czech Republic
UK	Thermometers, barometers, hygrometers	Russell Scientific Instruments Ltd., UK
DE	Thermometers, hydrometers, hygrometers	AMARELL GmbH & Co. KG, UK
NL	Barometers	H.N. Rose Barometers Schiedam, the Netherlands
BE	Barometers	Dingens Barometers, Belgium

According to the obtained information there are several manufacturers of barometers (not identified) for private customers that will discontinue the production by October 2009 when the ban on barometers for private applications enter into force.

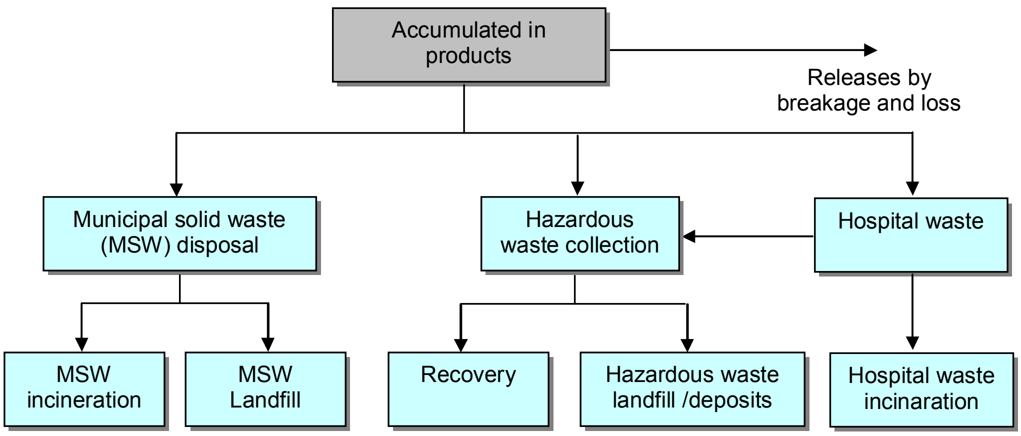
The same companies that produce the mercury-containing products are in general also producers or suppliers of alternative solutions. The number of manufacturers of mercury-free measuring equipment in the EU is quite high and it has been beyond the scope of the current project to identify all manufacturers of alternatives.

Mercury-free sphygmomanometers used for blood pressure measurements based on the auscultatory technique are manufactured in the EU by AC Cossor & Son (Surgical) Ltd (UK), Heine Optotechnik GmbH (Germany), Rudolf Riester GmbH & Co. KG (Germany), Germany, BOSCH + Sohn GmbH (Germany) and probably several other companies.

Electronic thermometers for professional uses are manufactured within the EU by several specialised companies among these WIKA Alexander Wiegand GmbH & Co. KG, Germany (production facilities in the EU and outside EU), Electronic Temperature Instruments (ETI) Ltd. UK, and Kjærulf Pedersen a/s, Denmark.

2.5.6 Collection and treatment of mercury waste

The main pathways of mercury in waste measuring equipment is shown in the diagram below. In most countries (if any) no separate collection system exists for mercury-containing measuring equipment, but the equipment is collected together with other types of hazardous waste and separated out and send for recycling. In the European waste catalogue mercury-containing equipment is included in a waste category together with fluorescent lamps and the waste quantities are totally shadowed by the large quantities of waste of fluorescent lamps. A substantial part of mercury in thermometers and other measuring equipment used in households is disposed of with municipal solid waste, and a substantial part of medical thermometers is disposed of with hospital waste for hospital waste incineration.



It has only been possible to obtain specific information on this waste type from a few Member States as shown in the table below. If the data are extrapolated to an EU-wide estimate the total would be 20-40 tonnes mercury, but the collection rate is probably significantly higher in the three countries than the EU average, as mercury has had a relatively high attention in these countries. As the use of mercury in measuring equipment has declined steeply the recent years it is further very difficult to extrapolate the 2007 figures from the reported data dating back to 2000-2003.

Considering the consumption of mercury with measuring equipment in the beginning of the 2000s at 15-30 it is roughly estimated that a similar amount was disposed of with waste in 2007.

It has not been possible to obtain newer estimates of the actual amounts of mercury recovered from wastes of measuring equipment.

Table 2-24 Reported waste of mercury in measuring and control equipment (based on questionnaire and stakeholder responses)

Country	Year	Tonnes waste	Tonnes mercury	Treatment
NL	2003	7.7	0.1-1.2	not indicated
DK	2001		0.2-0.8	0.2-0.7 exported for recycling, 0.02-0.06 incinerated or landfilled, respectively
FI	2000		0.4	Hg is separated from equipment before landfill, nearly 100% recycling

In 2002 Floyd *et al.* assumed, on the basis of Swedish experience, the following EU-wide emission factors: Release by breakage (5%), Collection (15%), disposal with solid waste (80%). With an increased awareness of separating mercury products from the general waste streak the collection is probably higher in the old Member States, but at the same time, the recycling rates in new Member states may be lower.

On the basis of limited actual data the distribution of 15-30 tonnes mercury is estimated as follows: 5% breakage, 20% collection, 60% in municipal solid waste and 15% hospital waste.

2.5.7 Data gaps

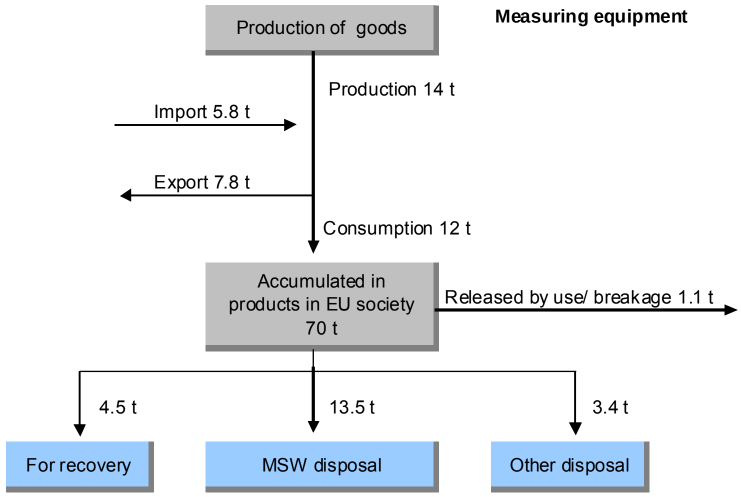
The actual consumption of mercury and accumulated quantities in society can for minor applications only be estimated with high uncertainty. It would however be very time consuming to obtain more accurate estimates.

Detailed quantitative data on export and import of mercury in products are not available. It is certain that different types of mercury-containing measuring devices are exported to non-EU countries.

Only few data are available for describing the waste handling situation for mercury-containing measuring equipment.

2.5.8 Mercury mass balance

The data obtained on the flow of mercury in measuring equipment are summarised in the flow-chart below.



2.6 Switches, relays and other electrical components

2.6.1 Applications of mercury and alternatives

Mercury has traditionally been used in a great variety of electrical switches, relays, arc rectifiers and thermostats. These components have been used in a variety of electrical and electronic equipment and vehicles.

Two EU directives, the ELV and the RoHS directive has had a significant influence of the use of mercury in the EU for electrical components.

ELV Directive

Mercury tilt switches and G-sensors have in the past been widely used in vehicles. With the Directive 2000/53/EC on end-of life vehicles (ELV Directive) the use in mercury in cars have been prohibited. An exemption has been granted for mercury in discharge lamps and instrument panel displays, but no exemption has been granted for mercury in switches, relays or other applications.

RoHS Directive

With the Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive), the use of mercury in electrical and electronic equipment has been prohibited. Mercury in some types of light sources is exempted from the directive, but no exemption has been granted for mercury in switches, relays or other applications.

However, two categories of equipment within the scope of the Directive 2002/96/EC on waste electrical and electronic equipment (the WEEE Directive) is today outside the scope of the RoHS Directive: Medical devices (group 8) and monitoring and control instruments (group 9). The two groups represent approximately 1% of the quantity of electrical and electronic equipment sold in the EU (Goodman and Robertson 2006), but may represent more than 1% of the mercury in switches and relays. Large-scale stationary industrial tools are outside the scope of both the RoHS and the WEEE directives, but monitoring and control instruments used in industrial installations is included in category 9.

A review of the remaining uses of the RoHS substances in the category 8 and 9 products has recently been undertaken for the European Commission (Goodman and Robertson 2006).

Based on the available information, mercury is still used in the EU for the following applications within this product group:

- Tilt switches:
  - Medical devices, laboratory equipment, alarm equipment, certain clocks, lifeboats, motion/vibration sensors, thermostats, G-force sensors and other applications;
  - Float switches and level sensors;
  - Thermostats.
- Thermoregulators;
- Mercury wetted reed relays;
- Mercury displacement relays.

For some of the discontinued uses significant amounts of mercury may still also be in circulation in society. This concerns in particular:

- G force-sensors in ABS brake systems and other applications in vehicles;
- Mercury pressure switches and displacement relays.

2.6.1.1 Mercury tilt switches

Mercury tilt switches are small tubes with electrical contacts at one end of the tube. As the tube tilts, the mercury collects at the lower end, providing a conductive path to complete the circuit. When the switch is tilted back, the circuit is broken.

Mercury tilt switches are still used for the following applications:

- In some medical devices and laboratory equipment;
- Motion/vibration sensors;
- Float switches and level switches;
- In certain clocks;
- Lifeboats;
- Thermostats.

The tilt switches typically contain from 0.5 g to 10 g mercury per switch.

Mercury tilt switches are manufactured by Russell Scientific Instruments Ltd., UK and Comus International Clifton, NJ, NY (USA). Comus International BVBA (Belgium) imports from the manufacturing site in the US and sells on the European market. According to information from market actors mercury tilt switches are further manufactured by only a few companies in the USA and Asia.

Motion/vibration sensors are very similar in design to tilt switches. Applications of vibration sensors include anti-theft devices, man-down alarms to detect non motion, smart appliances to turn off power when not in use and portable equipment to do the same (Comus 2007). Both mercury and mercury-free sensors are manufactured in the EU.

There are two basic types of **float switches**:

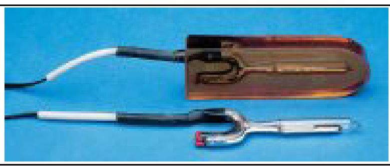
- Float switches located in a buoyant float housing and actuated by rising and falling liquid levels;
- Stationary float switches that is actuated by the presence or absence of liquid (level detectors).

A mechanical float switch is typically located in a buoyant float housing and is actuated based upon the rising and falling liquid levels. In the most common design, the lever arm is actuated by a metallic rolling ball that changes position based upon gravity and the position of the buoyant float housing.

Float switches are used for liquid monitoring and control of the liquid level in tanks, wells, chambers, drillings, and other containers. Float switches are used to actuate alarm and control circuits. Float switches have been used for monitoring various liquids including, among others, water, sewage, wet sludge, oil etc.

Mercury float switches are manufactured and marketed by several companies in the EU. The same companies typically also produce or supply mercury-free float switches. According to a manufacturer of float switches mercury switches are still used at least in Poland and Italy. Mercury switches may also be imported from Asian manufacturers.

Two manufacturers, ATMI (France) and Matic (Italy) have informed that they have recently stopped the production in response to the RoHS directive. In fact, monitoring and control equipment is beyond the scope of the Directive, and the use of mercury for this application is not prohibited.



Example

"*Resin-encapsulated, waterproof switch for use on lifeboats*." Manufacturer: Russell Scientific Instruments Ltd., UK.

Source: http://www.russell-scientific.co.uk/mercury_switches/mercury_switches.html

Example

"*A typical use is in a thermostat. A glass mercury switch is mounted to a bi-metallic spring which expands and contracts with temperature.*"

Supplier: Assemtech Europe Limited

Source.: http://www.assemtech.co.uk/productpages/tilt_tipover_switches_uk.asp

Examples

"*Float switches plastic*"

"*Float switches stainless steel*"

Supplier: E.L.B. Füllstandsgeräte GmbH+Co, Germany

Manufacturer: HERMETIKO Bauteile GmbH

Source: http://www.elb-bensheim.de/index_en.html

The mercury temperature switch (or **thermostat**) employs a temperature-response sensor, which is coupled to a mechanical means of activating a mercury tilt switch. The temperature-response sensor is typically either a thermocouple, resistance temperature detector (RTD), or gas-activated bourdon tube. Mercury thermostats are used in some applications outside the scope of the RoHS directive including laboratory equipment and industrial heat exchangers, ventilating equipment, alarm systems, pumps, motors, etc.

Alternatives
There are many mercury-free alternative technologies currently in use for tilt switch products and applications. These appear to be generally cost competitive and can meet the functional requirements for new tilt switch products and applications (Hansen *et al.* 2005). However, the mercury-free alternatives may not meet all requirements for retrofitting existing tilt switch products and applications.

A rolling metallic ball is used to make the actual electrical connection. The metallic ball moves with the movement of the tilt switch housing, or can be moved by actuator magnets using the principle of spherical magnetism.

The electrolytic tilt sensor contains multiple electrodes and is filled with an electrically conductive fluid. As the sensor tilts, the surface of the fluid remains level due to gravity. The conductivity between the electrodes is proportional to the length of electrode immersed in the fluid. Electrically, the sensor is similar to the potentiometer (see below), with resistance changing in proportion to tilt angle.

Potentiometers consist of a curved conductive track with a connection terminal at each end and a moveable wiper connected to a third terminal. As the shaft of the potentiometer is rotated, the length of the electrical path and resistance changes proportionally.

The mechanical tilt switch may be a snap-switch or micro-switch that may be actuated in a variety of methods, such as with a metallic rolling ball.

The solid-state tilt switch is often referred to as an inclinometer or accelerometer depending upon the application.

The capacitive tilt switch utilizes a capacitive based sensor that produces output directly proportional to the relative tilt.

A particular application of the mercury tilt switches mentioned for the Commissions Stakeholder Consultation for the EU Mercury Strategy is a **cut-off switch for lifeboats** that is activated if the lifeboat capsizes preventing the engine from flooding (Russell 2005). According to the manufacturer several alternatives have been tried and failed.

There were an exemption from the Swedish mercury ban until 31 December 2005 for electrical switches as spare parts for **personal motion alarms** which emit a radio signal indicating that the person is immobile if no change in position takes place within a certain period (Kemi 2004).

For **tracking devices for wildlife** there was according to the Swedish Chemical Inspectorate (KemI 2004) and the Norwegian EPA (SFT 2006) no satisfactory alternatives and therefore Swedish companies have sought and been granted dispensations to manufacture and sell them. Recently, the Swedish company TVP Positioning AB has developed an electronic device that satisfactorily can replace the mercury switch (Swedish EPA 2008).

Goodman and Robertson (2006) mention that a few remaining **position safety switches used in certain X-ray equipment** will be phased out by 2012.

A number of alternatives exist to mercury-containing **float switches and level sensors**. Prices are competitive for most of the mercury-free alternatives to float switches, although these mercury-free alternatives may not meet all requirements for retrofitting existing float switch products and applications.

In the magnetic dry reed switch, permanent magnets are embedded in the float housing that moves vertically along the tubing or stem. The reed switches are embedded in the stem. The magnets activate the reed switches in the stem at pre-determined levels for control or alarm purposes.

The optical float switch utilizes optical principles to detect the presence or absence of a liquid as compared with air. The sensor contains a small infrared LED and a phototransistor light receiver to detect the presence of liquid.

The conductivity float switch uses electrodes to measure conductivity and sense the presence or absence of a liquid. It relies on the conducting properties of liquids to complete an electrical circuit between electrodes, or between an electrode and the metal tank.

The conductivity float switch utilizes a sensor containing a piezoelectric crystal. The crystal excites oscillations, allowing the liquid level to be measured by oscillation frequency. As the probe tip becomes immersed in liquid the crystals acoustically couple and the switch changes state.

A gallium-indium alloy replicates many of the fluid and electrical properties of mercury. This alloy is used as a direct replacement of mercury within the switch.

The thermal float switch utilizes the thermal dispersion principle of the dissipation of heat by a liquid to detect the presence or absence of a liquid as compared with air. The sensor typically contains a resistor in the form of a thermistor. A thermistor is a semiconductor material that detects heat and converts heat into an electrical signal. The switch is actuated when heat generated by the thermistor is dissipated by a liquid.

The capacitance level float switch is typically comprised of two electrodes separated by an insulating medium. Air provides a reference capacitance value, and when the probe is covered by liquid the resultant capacitance change causes a signal to actuate the switch.

Hg-free alternatives, both digital and electromechanical **thermostats** can be as accurate as, or more accurate than, mercury devices. There have been reports of higher prices for some Hg-free thermostats, although, depending on the application, mercury-free thermostats may also be cheaper than their mercury equivalents. (Galligan *et al.* 2003)

Level of substitution and consumption of mercury with tilt switches
The major uses of mercury tilt switches has been phased out with the implementation of the RoHS and the ELV Directives.

Information from manufacturers indicate that mercury float switches has in recent year to a large extent been replaced by alternative switches. It has not been possible to identify applications for which float switches cannot be replaced, the applications of the mercury float switches are the same as for alternative mechanical float switches (ATMI 2008).

The market for tilt switches is steeply decreasing which is indicated by the fact that the sale of mercury switches from a major supplier in 2007 was only 1/3 of the level in 2005.

The consumption of mercury in tilt switches for equipment used in the EU in 2007 can based on information from manufacturers roughly be estimated at 300-500 kg of which nearly all is imported. It is from the obtained information not possible to split the total into the different specific applications. The export of tilt switches from the EU is estimated to be in the 100 kg range.

2.6.1.2 Thermoregulators

A **thermoregulator** (also designated contact thermometer or accustat) is a kind of thermostat, but applies another principle than the thermostats described under tilt switches. The thermoregulator may consist of a sealed glass unit with a regulating mechanism at the top, a calibrated section in degrees containing a spindle screw, a pointer mounted on a rider, and a glass stem which contains twin capillary bores which connect to a sensitive mercury filled bulb. Attached to the rider is a contact wire that extends into the capillary bore. A reservoir for storage of surplus mercury is also provided by extending a glass partition up into the adjustment section (Precision 2008). The thermoregulator may according to a producer be applied for providing a constant temperature in baths, ovens, incubators, circulating systems, alarm circuits, petroleum and asphalt testing etc. (Philadelphia 2008). In the EU thermoregulators are manufactured by Amarell GmbH and Co. KG (Germany) and Russell Scientific (UK) but other manufacturers probably exist as well. US manufactured thermoregulators are supplier in the UK (Cole-Parmer 2008a) and probably other Member States.

According to Goodman and Robertson (2006) mercury in switches, contacts, relays and thermostats has largely been phased out in most equipment wit big reductions in the quantity of mercury used. The market for mercury thermostats and thermoregulators in the EU is estimated to be very small and no attempt has been done to investigate it further. It is roughly estimated that the EU-wide mercury consumption for this application is 5-50 kg per year.

Alternatives
Digital electronic thermostats and thermoregulators are available for domestic and industrial type workloads and temperature control.

2.6.1.3 Mercury wetted reed switches and relays

A relay is an electrically controlled device that opens or closes electrical contacts to effect the operation of other devices in the same or another electrical circuit. Relays are often used to switch large current loads by supplying relatively small currents to a control circuit.

A mercury wetted reed relay is a type of electro-mechanical relay that employs a hermetically sealed mercury reed switch. The reeds are thin flat ferromagnetic blades that serve as a contact, spring, and magnetic armature. The mercury wetted reed relay consists of a glass encapsulated reed with its base immersed in a pool of mercury and the other end capable of moving between two sets of contacts. The mercury flows up the reed by capillary action and wets the contact surface of the reed and the stationary contacts. The mercury wetted reed relay is usually actuated by a coil around the capsule. Wetted mercury reed relays are typically small circuit controls that are used in electronic devices for switching or signal routing functions.

Reed relays are primarily used in test, calibration, and measurement equipment applications where stable contact resistance over the life of the product is necessary. The main market for mercury reed relays and switching devices are (Comus 2008b):

- Maintenance of older equipment;
- ATE markets: automatic test equipment, cable testers, high voltage testers, in-circuit testers;

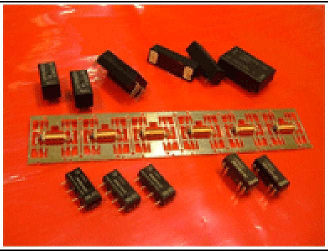
- Industrial instrumentation and control equipment, power plants;
- Transportation systems: railway circuits;
- Medical equipment.

Proximity switches, indicated in the literature as mercury-containing, may include a reed switch (Comus 2008a), and this is apparently the only mercury application in these switches.

The mercury content of the reed switches varies among the different types. According to information from the only manufacturer of mercury reed switches the mercury content of 5 basic types of mercury reed switches is as follows: HG switch (3 g Hg), HGW switch (0.32 g), HGX switch (0.071 g), MH4 switch (0.041 g) and MH5 switch (0.0095) (Comus 2008b)

Specific to RoHS category 8 and 9, only two manufacturer have asked for RoHS exemption concerning mercury in switches and relays in monitoring and control instruments not exceeding 20 mg of mercury per switch or relay. This implies according to Goodman and Robertson (2006) that most manufacturers intent to substitute the mercury wetted reed relays for mercury-free substitutes and have confidence that that this will be possible.

Mercury reed switches are manufactured by one company only, Comus International, Belgium. The switches are used to produce reed relays and switching devices by a number of companies (at least 6 companies within the EU), and the relays and switches devices are supplied to numerous customers who supply test and measurement and control/ instrumentation equipment in a variety of applications.



Examples:

"*Mercury Wetted Relays*"

"*Mercury wetted reed switches*"

Manufacturer: Comus International Bvba, Belgium

Source: http://www.comus.be/productpages/folders/Mercurywetted.pdf
http://www.comus.be/productpages/mercury_wetted_relays.asp

Alternatives

There are several alternatives to mercury wetted reed relays available which include field effect transistors (FETs), electromechanical switches, coaxial switches and standard radio frequency microelectromechanical systems (RF MEMS) (Goodman and Robertson 2006). Further, a new design in mercury switches containing 5 mg or less of mercury has been developed by the US manufacturer Agilent Technologies (Goodman and Robertson 2006). It is called a Liquid Metal Micro-Switch (LiMMS) and operates by moving a small bead of mercury between two positions in a glass microchannel by means of heated gas in two small side chambers.

Goodman and Robertson (2006) compares the various switches on a number of parameters and conclude that the LiMMS has the best or nearly the best performances for most of the parameters in the table and that the mercury micro switches have a unique combination of properties which cannot be achieved by the other switches currently available.

Level of substitution and mercury consumption with reed relays
Mercury wetted relays have been replaced by alternatives for all other applications than group 8 and 9 applications and manufacturers seems to be planning to change to mercury-free alternatives for most applications. According to Goodman and Robertson (2006) there are a small number of applications where only mercury-based switches meets all of the essential technical requirements and that is very high accuracy instruments for calibration of standard capacitance and loss instruments and test equipment used for very high radio frequency equipment mainly used for telecommunication.

California and other US states have banned the use of mercury in a wide range of products and this accounts for the current trend to replace mercury wetted reed relays wherever it is possible (Goodman and Robertson 2006).

The European market for reed switches (for manufacturing of relays and switching devices in Europe) have been declining since the 1990s but have been fairly stable in recent years at a level of about 90.000 units per year with a total mercury content of about 25 kg. The switches are imported and exported with the equipment and the total mercury content of instruments used in the EU (end use of the switches and relays) may quite well be higher than the 25 kg used in production and it roughly estimated at 25-50 kg.

About 130 kg mercury is used annually for production of reed switches in the EU, the main part of the switches being exported for manufacturing of reed relays and switching devises in the USA and Asia. The mercury use for production was about 3 times higher 10 years ago.

2.6.1.4 Mercury displacement relay and contactors

Mercury displacement relays and contactors have been used in high-current, high-voltage applications such as industrial process controllers, power supply switching, resistance heating, tungsten lighting, welding, high current/voltage lighting, flood lights, copiers, battery chargers, energy management systems, and industrial ovens. Applications in e.g. industrial process controllers are beyond of the current scope of the RoHS directive.

The displacement relay uses a metallic plunger device to displace mercury. The plunger is lighter than mercury so it floats on the mercury. The plunger provides the same functionality in a mercury displacement relay as an armature in a mechanical relay. When the coil power is off, the mercury level is below the electrode tip and no current path exists between the insulated centre electrode and the mercury pool. When coil power is applied, the plunger is drawn down into the mercury pool by the pull of the magnetic field and the plunger centres itself within the current path. The mercury content reported by manufacturers of relays is in the range of greater than 1 g (Galligan *et al.* 2003).

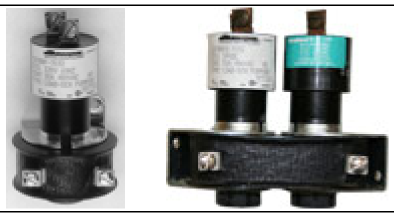
An internet search has identified that displacement relays and contactors are still manufactured by e.g. Mercury Displacement Industries Inc., USA. (MDI 2008) and American Electronic Components (AEC 2008), but no European manufacturers of the relays have been identified. US produced mercury contactors are supplied by a number of companies in the EU. According to one UK supplier, the mercury relays and contactors from Mercury Displacement Industries are used for (ICD 2008):

- Electric heaters on plastic extruders, drying ovens, injection moulding machines and glass furnaces;

- Lighting for street lamps, airport runways, stage lighting and flood lights;
- Motor starting, air conditioning, battery chargers, test panels and mining equipment.

An example of equipment containing mercury contactors marketed in the EU is an AEC temperature controller from Demag Hamilton (Demag Hamilton 2008).

In spite of the fact that mercury relays and contactors are marketed in the EU it is estimated that the total mercury consumption for this application is relatively small, and the EU-wide mercury consumption for this application is estimated at 10-100 kg per year.



Examples

BB and BB2 mercury contactors

Supplier: Willow technologies Ltd., UK

Manufacturer: American Electronic Components, Inc., USA

Source: http://www.willow.co.uk/html/mercury_relays___contactors.html

Alternatives

A large number of different relays and contactors are marketed as alternatives to mercury relays and contactors. An example of relays specifically marketed as cost-effective alternatives to mercury contactors is the E-SAFE mercury-free relays system from Watlow (former producer of mercury relays and contactors) (Watlow 2004).

2.6.1.5 Pressure switches

The mercury pressure switch typically uses a piston, diaphragm, or bellows acting as the pressure sensor to actuate the mercury switch. Listed below are examples of EE products and applications that in the literature have been reported to include pressure switches:

- Heating, ventilation, and air conditioning: electrostatic air cleaners, filter indicators, reservoir level, gas-fired heating, ventilation, utility heaters, heat pumps, furnaces, flue gas, fuel delivery, etc.

- Medical: respiratory sensors, therapy tent nebulizers, automated blood pressure systems, sip-and-puff movement controls, anaesthesia leak detection, saline pumps, tourniquet systems, reverse osmosis purification systems, dental aspirator pumps, respiratory therapy, disposable surgical vacuum systems, etc.

- Appliance: floor scrubbers, vacuum cleaners, food storage sealers, air conditioners, hot water dispensers, hot water heaters, etc.

- Other: venting hoods, tape braking systems, tape tension controls, door safety, spa pumps, boilers, garage doors, vacuum radon detection, pump control, pressurized air systems, sanitary systems, altitude sensing, fire protection systems.

Most of the applications are covered by the RoHS Directive, but some applications in medical equipment and control equipment are beyond the scope. A review of the remaining uses of the RoHS substances in the category 8 and 9 products, recently undertaken for the European Commission, do not mention mercury pressure switches (Goodman and Robertson 2006).

It has not via the internet been possible to obtain any evidence of current use of mercury in pressure switches, and it is estimated that the mercury consumption with pressure switches, if any, is less than 50 kg.

Alternatives
There are a couple of mercury-free alternative technologies (below) currently in use for pressure switch products and applications, which appear to be cost competitive and can meet the functional requirements for new pressure switch products and applications (Hansen *et al.* 2005). However, they may not be suitable for all retrofits.

The mechanical pressure switch typically uses a piston, diaphragm, bellows, or combination piston/diaphragm as the pressure sensor. The sensor can either 1) directly activate a switch, or 2) use a push-rod, lever, or compression spring to activate a snap-acting micro-switch.

Solid-state pressure switches contain one or more strain gauge pressure sensors, a transmitter, and one or more switches – all in a compact package. In addition to opening or closing the pressure switch circuit, they can provide a proportional analogue or digital output. Diffused silicon piezo-resistive sensors are widely used in solid-state pressure switches.

2.6.1.6 G-force sensors and light switches in vehicles

The application of mercury is prohibited by the ELV directive which also stipulates that all components identified as containing mercury as far as feasible shall be removed by the end of the life of the vehicle.

Mercury has been extensively used in vehicles for tilt light switches and G-force sensors in ABS systems, air bag sensors and auto seat belt mechanisms.

The G-force sensor systems typically contained three one-gram mercury switch capsules embedded in a solid plastic component (Clean Car Campaign 2008). The average amounts of mercury switches per car in vehicles produced in the USA increased from 1997 to 2002 from 0.3 to 0.6 (Clean Car Campaign 2004). The sensors were also used in some older automobile air bag sensors and auto seat belt mechanisms (Floyd *et al.*, 2001). The sensors may be present in older cars in use, but no data have been available on the total accumulated quantities in the EU. In the USA, it was estimated that vehicles retired in 2003 contained about 9 tonnes of mercury in switches, while the entire vehicle fleet was roughly estimated to contain in total 123 tonnes mercury (Clean Car Campaign 2004).

The estimate could indicate that also considerable amount of mercury may have been accumulated in the vehicle fleet in the EU. Instruction for removal of mercury-containing light switches in engine room and trunk, as well as G-force sensors in ABS systems and airbags by vehicle brand have e.g. been published by the Danish system for recycling of end of life vehicles (Miljøordning for Biler 2008). According to the instruction the most recent application in vehicles was G-force sensors in airbags in some Ford, Lexus and Subaru models until 1996, while the use was phased out in most models in the beginning of the 1990s. In many major brands like Opel, Fiat, Renault and Honda mercury contacts were never used.

As mercury contacts would only be present in vehicles of more than 11 years of age, and only in vehicles of a few brands it is estimated that the total mercury content of the EU vehicle fleet in contacts is probably less than 1 tonne.

2.6.1.7 Flame sensors

Flame sensors, also called automatic gas shut-off or safety valves, have been used as safety devices in gas and gas-electric ranges and other appliances. The mercury within the bulb of the sensor vaporizes and expands when the pilot light is on, causing the gas valve to open. The flame sensor stops the flow of gas if the open flame does not produce heat, such as when the pilot light (either standing pilot or electronic ignition pilot) is not lit. Most of the traditional uses of flame sensors fall within the scope of the RoHS directive and there is reason to believe that the use of mercury for flame sensors in the EU today will be negligible.

2.6.1.8 Mercury arc rectifiers

Mercury arc rectifiers are used to convert alternating current into direct current. Different types exist, among these the “ignitrons” and “excitrons”. Mercury rectifiers were used in electric motor power supplies for industry, in electric railways, streetcars and diesel-electric locomotives. The historical use is e.g. demonstrated in the “Mercury virtual arc rectified museum” (2008). Small rectifies were also used in different electronic equipment. By the 1970s, the development of high-voltage solid state devices made the mercury arc rectifier obsolete even in high-voltage DC applications (Wikipedia 2008). Mercury content of rectifiers used for industry welding unit, old IT equipment and sound systems, and projectors is reported to be up to 1 kg (Naturvårdsverket 2003). It has not been possible to identify mercury rectifiers marketed in the EU, but it cannot be ruled out that a few are marketed for some very specific high pulse applications. Some old rectifiers may still be used in society, but the total mercury content accumulated in such equipment is estimated to be relatively low.

2.6.2 Current use and trade of mercury

Goodman and Robertson (2006) estimate the use of mercury in switches in category 8 equipment at 0.001 tonne per year and in category 9 equipment at 6 tonne per year in 2002. Based on the assumption that most of the applications have been phased out, they estimate the total mercury consumption with category 8 and 9 equipment in 2006 at 0.2 kg, but indicate in the notes that the actual figures could be higher.

Based on the information obtained from manufacturers of this equipment the total mercury consumption with switches, relays and other electrical components is here estimates at 0.3-0.8 tonnes (Table 2-25) somewhat higher than the estimate provided by Goodman and Robertson (2006).

Table 2-25 Mercury consumption with switches and relays in 2007

Application	Consumption Tonnes Hg/year
Tilt switches for all applications	0.3 - 0.5
Thermoregulators	0.005 - 0.05
Reed relays and switches	0.025 - 0.05
Other switches and relays	0.01 - 0.15
Total (round)	0.3 - 0.8

2.6.3 Mercury accumulated in society

The mercury accumulated in society with measuring switches, relays and other electrical equipment can be estimated on the basis of historical consumption figures and knowledge on the average life-time of the equipment in which the components are used.

The actual life of the typical products range from a few years to more than 20 years. Floyd *et al.* (2002) assume that the average lifetime is in the range of 5 to 10 years. It will conservatory be estimated that the quantity of mercury accumulated today resemble the last ten years consumption based on the trend line shown in Figure 2-6. On this basis the amounts of mercury accumulated in these products is estimated at about 125 tonnes.

A survey of mercury stored in technical products in Sweden in 2002 (as reported by Floyd *et al.* 2002) showed that 33-40 tonnes mercury was accumulated in such products broken down into 22-24 tonnes in electrical and technical products in industry (including thermometers and other measuring equipment), 2-3 tonnes in electronics in products, 1-2 tonnes in products for general household uses (heating oil-level indicators, doorbells, other unusual applications), 1.8 tonnes in rectifiers for sea cables, 1 tonnes in cars and 0.3 tonnes in white goods switches. Considering the limited application of mercury in new products the last 6 years, the accumulated amount must be expected to be significantly lower today.

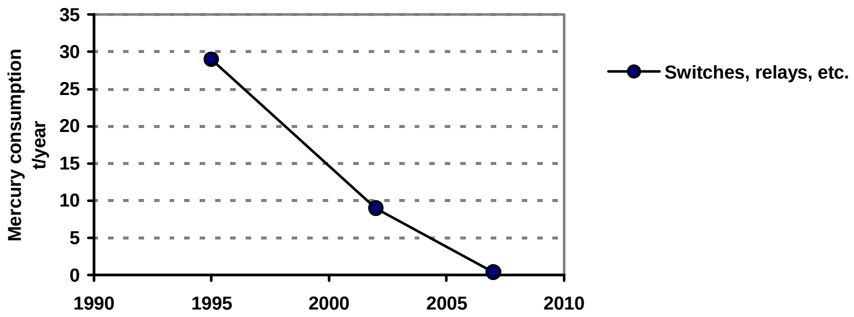


Figure 2-6 Estimated consumption of mercury in switches, relays and other electrical components in 1995 (EU15 based on WS Atkins 1998), 2002 (EU15 + 3 based on Floyd et al. 2002) and 2007 (EU27+2)

2.6.4 Mercury-free alternatives

A summary of the information regarding alternatives to mercury-containing switches and relays is shown in Table 2-26. The background for the table is described in the previous section.

The indicated substitution level is based on information on substitution level provided by Member States (see Annex 1) supplemented by an assessment made by the authors. A range indicates that different substitution levels are reached in different Member States.

Table 2-26 Overview of marketed alternatives to mercury-containing switches and other electrical components

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Tilt switch for general applications	Many mercury-free alternative technologies currently in use for tilt switch products and application	=	3-4	
Motion sensors for personal alarms and tracking wildlife	Electronic devices. Alternatives may not available for some applications	N	0-4	For some applications replacement may have taken place, but for some specific applications alternatives may not to be available
Float switch	Alternatives include magnetic dry switch, optical float switch, conductivity float switch, conductivity float switch, thermistor switch, capacitance level float switch	=	3-4	
Pressure switch	Couple of mercury-free alternative technologies	=		
Thermostats and thermoregulators	Couple of mercury-free alternative technologies both digital and electromechanical thermostats	=	3-4	
Mercury displacement relay	Alternatives to mercury relays include dry magnetic reed relays and other electro-mechanical relays, such as general purpose, specific purpose, heavy duty, and printed circuit board mounted relays.	=	3-4	Alternatives have been de-signed specifically for use in most applications, including demanding process control applications, although retrofits may pose problems for some equipment (primarily due to equipment design)
Mercury wetted reed relay	Alternatives include field effect transistors (FETs), electromechanical switches, coaxial switches and standard radio frequency microelectro-mechanical system	=/+	3-4	Has been replaced for all other applications than WEEE group 8 and 9 applications. There are a small number of applications where only mercury-based switches meets all of the essential technical requirements

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Flame sensor	Using an electronic ignition system in gas appliances eliminates the need for a standing pilot light, and is generally a viable alternative. Most manufacturers also make a mercury-free electronic ignition flame detection unit.	=	4	Alternatives are readily available and have largely replaced mercury flame sensors already.

Key assigned to the overall current user/consumer price levels for mercury-free alternatives as compared to mercury technology:

– Lower price level (the alternative is cheaper)
= About the same price level
\+ Higher price level
++ Significant higher price levels (more than 5 times higher)
N Not enough data to assign an indicator

Key to assigned substitution level indices:

0 No substitution indicated in assessed data sources; development often underway
1 Alternatives are in commercial maturation, or are present on the market but with marginal market shares
2 Alternatives are commercially matured and have significant market shares, but do not dominate the market
3 Alternatives dominate the market, but new products with mercury also have significant market shares
4 Mercury use is fully, or almost fully, substituted
N Not enough data found to assign an indicator
? Indicator very uncertain due to limited data

2.6.5 Producers of mercury-containing products in the EU

The following list of manufactures of mercury-containing switches and relays in the EU is based on Member State responses to the questionnaire, internet search and contact to market players. The list is not considered comprehensive, but is deemed to include the major manufacturers for each product group.

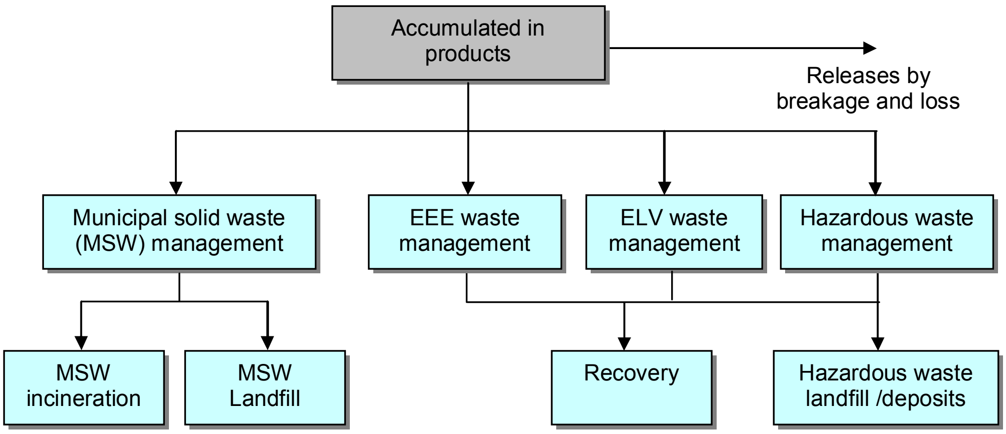
Country	Product type	Name of producer
UK	Mercury vibration sensors	Cooper Menvier Ltd., UK
BE	Mercury wetted reed switches and relays, vibration sensors, tilt switches, float switches	Comus International Bvba, Belgium (manufacturing of the tilt switches by Comus in the USA)
DE	Mercury float switches	HERMETIKO Bauteile GmbH, Germany
IT	Mercury float switches	MATIC s.r.l., Italy - mercury switches manufactured for export to non EU countries only
UK	Mercury tilt switches	Russell Scientific Instruments Ltd., UK

Many of the manufacturers of mercury-containing equipment also manufacture or supply mercury-free alternatives. A large number of manufacturers of alternatives to the mercury-containing devices exits in the EU, and it has been beyond the scope of this study to provide an overview of manufacturers of alternatives.

2.6.6 Collection and treatment of waste

The pathways of mercury in waste switches, relays and other electrical equipment is shown in the diagram below. The schemes in the different Member States may have changed significantly the recent years with the implementation of the WEEE Directive and the ELV Directive.

The main pathway for electrical mercury components is today probably via management of electrical and electronic equipment (EEE) in accordance with the WEEE directive. Contrary to the RoHS Directive, restricting the use of mercury in new EEE, the WEEE directive also covers medical equipment and measuring and control equipment in which a significant part of the mercury-containing components have been used. Mercury from some large electrical equipment may still be drained before disposal of the equipment and the mercury is disposed of as part of the general hazardous waste management system. Mercury switches and G-force sensors in vehicles shall be removed from cars in accordance with the ELV Directive.



Although in principle all EEE waste shall be collected and treated, a significant part of EEE waste from households and small enterprises may still end up in municipal solid waste.

Very limited information on the actual quantities of mercury switches, relays and other electrical components in the waste stream is available. In the statistics the components (apart from the switches in vehicles) is included in the category "fluorescent tubes and other mercury-containing waste" which means that the quantities are overshadowed by the large quantities of fluorescent tubes.

The total amount of mercury in wastes of switches and relays disposed of today is estimated to be within the range of 19 tonnes (corresponding to the consumption in 1995) and 9 tonnes corresponding to the consumption in 2002; with the highest likelihood of being in the upper end. The significant part of the mercury will be included in waste electrical and electronic equipment and the collection efficiency of this equipment may be used to indicate the amount actually collected. The collection efficiency of selected groups of WEEE is as follows: large household appliances (16.3%), medical devices (49.7%), Monitoring and control instruments (65.2%) Huisman *et al.* 2007). Based on this it is roughly estimated that 50% of the mercury in this product group (5-9 tonnes) is disposed of for recycling, while 40% goes to municipal solid waste disposal and 10% is disposed of in other ways. The releases by breakage is estimated to be insignificant.

2.6.7 Data gaps

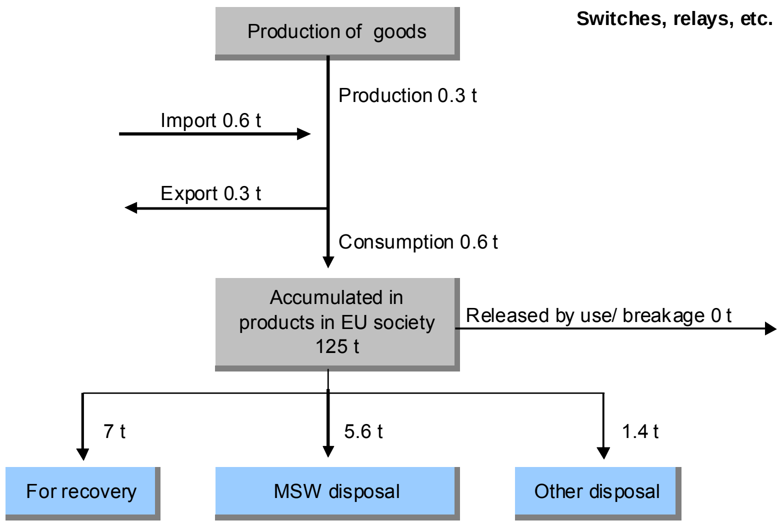
Very limited information on the use of switches in imported products is available, however, the total mercury consumption in such products is estimated to be relatively small.

Limited information on the current application of mercury displacement relay and contactors is available. The relays and contactors are mainly imported, and it would be difficult to obtain an overview of the entire EU market. The total mercury consumption is considered to be relatively small and alternatives seems to be available for all applications.

Limited information is available on quantities of mercury actually recovered from this product group.

2.6.8 Mercury mass balance

The obtained data on the flow of mercury with switches and relays are summarised in the flow-chart below. The amount disposed of today reflects the uses of switches in products 5 to 15 years ago and is roughly estimated at a total of 10-18 tonnes of which it is estimated that 50% is disposed of for recovery, 40% goes to municipal solid waste disposal and 10% is disposed of in other ways.



2.7 Mercury chemicals

2.7.1 Application of mercury chemicals

Mercury chemicals are defined here to include both metallic mercury and mercury compounds used for a wide range of process, additive, reactive and laboratory applications not covered in other sections of this report. As in the case of metallic mercury, many of the mercury compounds have highly attractive, and sometimes unique properties.

In addition to simple mercury "salts," such as compounds of chloride, nitrate and sulphate, mercury (II) forms an important class of organometallic compounds. These are characterized by the attachment of mercury to either one or two carbon atoms. The carbon-mercury bond is chemically stable. It is not split in water, or by weak acids or bases. The stability of the carbon-mercury bond is not due to its high strength, but rather to the very low affinity of mercury for oxygen. The organic part of the compound may take a variety of forms, some of the most common being alkyl, phenyl, and methoxyethyl. If the anion part of the compound is a nitrate or sulphate, the compound tends to be “salt-like”, having appreciable solubility in water. In general, mercury reacts directly with the halogens to form mercuric salts; however, the chlorides are covalent, non-polar compounds that are more soluble in organic solvents than in water. The chloride compounds are also more challenging to recycle.

From the toxicological standpoint, the most important of the organometallic compounds is the subclass of short-chain alkyl mercurials in which mercury is attached to the carbon atom of a methyl, ethyl, or propyl group (OECD 1995).

Well over 100 mercury chemicals are marketed in the EU (e.g. Chemos 2008). 41 of these compounds were selected for further investigation, and actual sale on the EU market has been confirmed by the industry for more than 75% of the selected compounds. In addition, there are significant imports and exports of mercury compounds between EU and non-EU countries.

The main EU applications of mercury compounds are:

- Production of batteries or parts of batteries (included in section 2.3);
- Production of reference electrodes (included in section 2.5);
- Catalyst in production of polyurethanes;
- Chemical intermediate in the pharmaceutical industry;
- Chemical intermediate for production of other mercury compounds;
- Laboratory chemical reagents for COD analyses and a number of analyses in the medical and food sector;
- Mercury standards for calibration;
- Preservative in vaccines, eye/nasal preparations;
- Preservative and fungicide in paints;
- Disinfection of medical equipment and process equipment;
- Disinfectants for veterinary uses;
- Pigment for artwork and restoration.

For some applications of mercury compounds described in the literature it has not been possible to find any evidence of present use in the EU. It cannot be ruled out that such uses in some products may find their way to the EU market, but it is estimated that the total volume of mercury with those products will be quite low. The applications in question include:

- Mercury fulminate, $Hg(ONC)_2$, used as a detonator for explosives, in ammunition and in fireworks;
- Certain types of colour photograph paper;
- Fireworks;
- Pesticides containing mercury;
- Tanning and preparation of felt.

The overall market for mercury chemicals has been investigated by requests to 11 well-placed companies in the business of mercury and mercury compounds, and/or substitutes, in the EU:

- Acros (BE)
- Bome (CZ)
- CFMOT (DE)
- Chemos (DE)
- Fox Chemicals (DE)
- Gomensoro (ESP)

- Johnson-Matthey (UK)
- Lambert Metals (UK)
- Mayasa/Minas de Almadén (ESP)
- Safina (CZ)
- Scharlab (ESP)

Seven of the companies were requested to provide their best estimates of the EU-wide consumption of 41 listed chemicals and to indicate the main applications. Only one company provided a full overview, whereas other companies provided partial information. The result of the enquiry is shown in Table 2-27 overleaf. Please note that indicated quantities are in tonnes of compounds, whereas the mercury quantities are somewhat less.

Eight compounds are indicated to be used in the EU in quantities above 0.5 tonnes (indicated in bold): Mercury-I-chloride, mercury-II-chloride, mercury-II-oxide, phenylmercury acetate, phenylmercury neodecanoate, phenylmercury octoate, mercurochrome and phenylmercury-2-ethylhexanoate (indicated in Italy, questionnaire response).

Slovenia (questionnaire response, 2008) reported that about 5 tonnes mercury is used for production of mercury compounds in the country, especially mercuric chloride, mercuric oxide and phenylmercuric acetate. About 2 tonnes were exported in 2006 while the consumption within the country in compounds is estimated at 5.1 tonnes (including imported compounds).

Table 2-27 Mercury compounds marketed in the EU and their main applications. Market volume as estimated by major suppliers of mercury chemicals

Hg compound	CAS number	Hg content	Main applications in the EU	EU market 2006 in tonnes compound						
				~ 0	<0.01	0.01-0.1	0.1-0.5	0.5-5	5-15	>15
Inorganic compounds:										
Mercury-II-bromide	7789-47-1	56	Laboratory analyses		x					
Mercury-I-chloride, mercurous chloride	10112-91-1	85	Medicine, acousto-optical filters, used as a standard in electrochemistry, agricultural chemical, insecticide, fungicide						x	
Mercury-II-chloride, mercuric chloride	7487-94-7	74	Pharmaceutical industry, disinfectant, preservative, metallurgy, chemical intermediate							x
Mercury-II-cyanide	592-04-1	80	Pharmaceutical, germicidal soaps, photography and in making cyanogen gas		x					
Mercury-I-fluoride	13967-25-4	91		x						
Mercury-II-fluoride	7783-39-3	84		x						
Mercury iodide	7783-30-4	61	Disinfectant soaps				x			
Mercury-I-iodide	15385-57-6	61	Topical disinfectant, bactericide	x						
Mercury-II-iodide, red – mercuric iodide	7774-29-0	44	Pharmaceutical industry, Laboratory analyses							
Mercury-I-nitrate, mercurous nitrate	10415-75-5 14836-60-3	76	Laboratory analyses: Millon's Protein Test Reagent		x					
Mercury-II-nitrate, mercuric nitrate	10045-94-0	62	Laboratory analyses		x					
Mercury oxycyanide	1335-31-5	86	Disinfectant		x					
Mercury-II-oxide mercuric oxide	21908-53-2	93	Batteries, cosmetics, paint pigment, perfumes, pharmaceuticals, polishing compounds, fungicides, chemical intermediate						x	
Mercury-II-sulfate, mercuric sulfate	7783-35-9	68	Laboratory analyses: COD analysis, Kjeldahl method, pharmaceutical industry				x			
Mercury-II-sulfide, cinnabar, red mercury sulphide	1344-48-5	86	Pharmaceutical industry, artistic paints			x				

Hg compound	CAS number	Hg content	Main applications in the EU	EU market 2006 in tonnes compound						
				~ 0	<0.01	0.01-0.1	0.1-0.5	0.5-5	5-15	>15
Mercury-II-thiocyanate	592-85-8	63	Pharmaceutical industry, photography				x			
Mercury-I-perchlorate	65202-12-2	67	Chemical intermediate							
Mercury-II-perchlorate	7616-83-3	50	Chemical intermediate							
Mercury potassium iodide	7783-33-7	26	Laboratory: Nessler's reagent			x				
Mercury II selenide	20601-83-6	72		x						
Mercury silver iodide	7784-03-4	22	Disinfectant	x						
Mercury II telluride	12068-90-5	61	Semiconductors	x						
Mercury fulminate	628-86-4	70	Explosives, detonators	x						
Mercury-II-hydride	72172-67-9	99	Chemical intermediate	x						
Organic compounds:										
Mercury-II-acetate	1600-27-7	63	Pharmaceutical industry							
Mercury-II-ammonium chloride, ammoniated mercury	10124-48-8	80	Pharmaceutical industry				x exp.			
Phenylmercury acetate	62-38-4	60	Fungal control (e.g. paints, building materials), catalyst for polyurethane production							x
Phenylmercuric borate	102-98-7	59	Pharmaceutical industry		x					
Diphenylmercury	587-85-9	57	Pharmaceutical industry, catalyst for isocyanate-hydroxyl reactions		x					
Phenylmercury neodecanoate	26545-49-3	45	Catalyst in polyurethane elastomers							x
Phenylmercury nitrate	55-68-5	59	Pharmaceutical industry		x					
Phenylmercury-II-nitrate	8003-05-2	67	Pharmaceutical industry							
Phenylmercury oleate	104-60-9	36								
Phenylmercury octoate	7439-98-7	?	Bactericide, fungicide, polyurethane catalyst				x			
Diethyl mercury	627-44-1	78	Laboratory analyses		x					

Hg compound	CAS number	Hg content	Main applications in the EU	EU market 2006 in tonnes compound						
				~ 0	<0.01	0.01-0.1	0.1-0.5	0.5-5	5-15	>15
Dimethyl mercury	593-74-8	87	Laboratory analyses, toxicology, calibration, antifungal agents, insecticides		x					
Phenylmercuric propionate	103-27-5	57	Catalyst in polyurethane elastomers							
Thimerosal, thiomersal, merthiolate	54-64-8	50	Preservative in vaccines, drops and ointments for eyes, in blood plasmas, in veterinary medicine and for antiseptic surgical dressing				x			
Mercurochrome, merbromin, mercury dibromofluorescein	129-16-8	27	Disinfecting, antiseptic, pharmaceutical industry					x		
Mercury methanesulfonate	29526-41-8	68								
Phenylmercuric 2-ethylhexanoate	13302-00-6	58	Bactericide, fungicide in paints							

2.7.1.1 Use as a chemical intermediate or catalyst

Heavy metals are involved in chemical synthesis: 1) if the feedstock or product contains heavy metals, or 2) if the heavy metals are used as auxiliaries (e.g. catalysts, redox partners) (BREF Fine Chemicals 2006).

A chemical "intermediate" is normally thought of as a substance or compound that plays a role in one or more of a series of reactions necessary to convert certain chemical raw materials to another form or to final products. The chemical intermediate may be "consumed" and/or generate wastes, and it may or may not remain in trace quantities in the final product.

Mercury (II) chloride is commonly used as an intermediate for the production of other mercury compounds like thimerosal and phenylmercuric chloride. Other intermediates, based on indications from industry, while far from a complete list, include phenylmercury borate, phenylmercury nitrate, mercury-II-chloride, mercury-II-sulfate, mercury-II-sulfide, mercury-II-thiocyanate, mercury-I-perchlorate, mercury-II-perchlorate and mercury-II-acetate.

Heavy metals such as mercury, copper, zinc or tin as a metal or as a chloride are commonly employed in intermediate chemical process "reductions" (BREF Fine Chemicals 2006).

There is some confusion in the literature as to the definition of "catalyst." In some applications a catalyst is a compound that enhances the chemical process but is not consumed by the process. In other applications a catalyst is added in small amounts to a batch process, for example, in order to give the batch and/or the final product certain desirable characteristics.

As stated by one of the main EU suppliers of mercury compounds, "A large number of our customers use metals and metal compounds for producing metal salt catalysts which in turn are used for the production of pharmaceutic intermediates" (CFMOT website).

One of the main difficulties in obtaining an overview of the use of mercury compounds as chemical intermediates and as catalysts is that specialty chemicals or fine chemicals are sometimes designed and patented for a specific process, if not for a single industry. For example, one manufacturer of catalysts reports:

"*We have a broad range of products and synthesis technologies that provide pharmaceutical companies with a unique combination of intermediates and customer manufacturing capabilities. ... Our intermediates are used in over 50 prescription drugs, veterinary medicines, and nutritional supplements*" (Vertellus 2008c). Since it is not realistic within the scope of this report to identify all mercury compounds used as intermediates, the quantities of mercury involved will be included in the broader discussion of compounds marketed in the EU as indicated by industry contacts.

Likewise, considering the many applications, it is clear that for some or many of the applications no viable alternatives have been identified. At the same time, it is useful to note that until recently there has been relatively little incentive to search for alternatives.

2.7.1.2 Used as catalyst in the production of polyurethanes

In polyurethane manufacture, for many applications, the catalysts of choice for catalysing the reaction between a polyol and an isocyanate composition, i.e., for hardening or curing polyurethane (PU) materials, have long been organic mercury compounds. This is because, for a wide range of polyurethane materials, these catalysts provide a robust and desirable "reaction profile" characterised by:

- an initial induction period in which the reaction is either very slow or does not take place, which continues for sufficient time to permit the "system" (combination of polyurethane materials and catalyst) to be mixed and cast (or sprayed); and
- a subsequent rapid reaction period during which the product cures, taking on its final properties (shape, hardness, flexibility, strength, etc.).

There are special properties sometimes required of these catalysts, like long "pot life" (see below), with a sharp viscosity rise toward the end of the reaction, followed by a "fast" curing of the part. In contrast to PU foam manufacture, the formation of bubbles and foam is undesirable in polyurethane elastomer production. For this reason, heavy metals such as mercury have long been used in catalysts as they exhibit the high reactivity and selectivity required in the process.

A reasonable induction time (also known as the "gel time" or "pot life") before hardening, which may be easily varied when using a mercury catalyst, e.g. by changing the amount of catalyst added, is desirable because it allows the liquid reaction mixture to be cast (poured or moulded) after addition of the catalyst, and therefore gives the user more control over the application. A rapid and complete reaction after the gel time is important to provide finished articles that are not sticky and that develop their desired physical properties quickly after casting, which allows fast turnaround in the production facility or at the site of application.

Relevant applications
In past years mercury was extensively used as a catalyst to promote a large range of polymer reactions. For example, vinyl acetate can be produced using mercury salts as a catalyst (ATSDR Toxicological Profile for vinyl acetate, as cited by the UNEP Mercury Toolkit (UNEP 2005), although there is reported to be little if any of this process remaining in the EU. A palladium catalyst is typically used instead.

Nowadays organic mercury compounds remain a very important catalyst in one particular niche, which is the production of polyurethane elastomers, in particular for PU elastomers that are cast (poured or injected into a mould) into sometimes complex shapes, or sprayed onto a surface as insulation, corrosion protection, etc. It is estimated that PU elastomer castings and coatings comprise at least 90% of the total applications of PU elastomers (industry communications).

It is likely that there remain in the EU some other polymers and adhesives that use mercury catalysts, but these are likely very specialised applications and the volumes of catalyst used are minimal (industry communications).

Some typical applications for PU elastomers are shown in Table 2-28. Promotional literature generally characterises different "systems" initially by their hardness or durability. In Table 2-28, most of the elastomers are cured with a mercury catalyst.

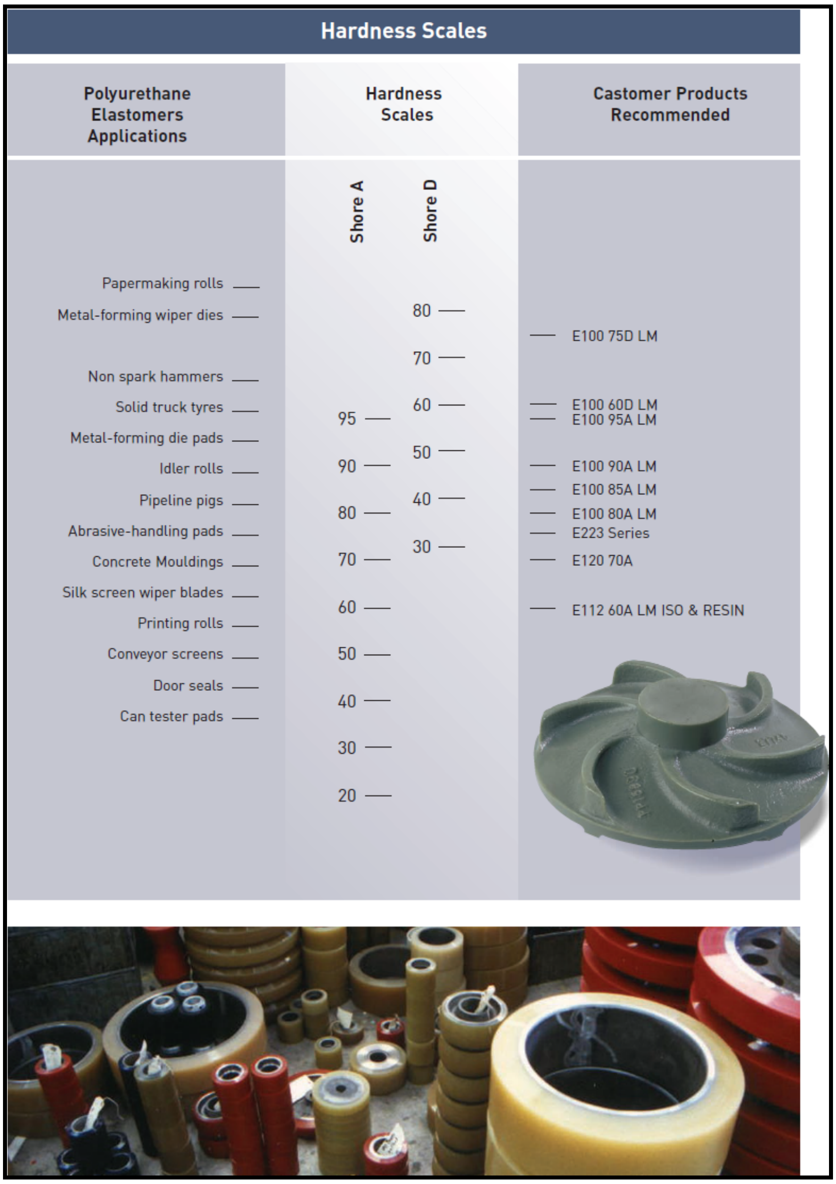
Table 2-28 Some Polymed Ltd. PU elastomers – most of them Hg-catalysed (Polymed 2008)

<table>
<tr><th>Product code</th><th>Hardness (Shore A)</th><th>Description</th><th>Applications</th></tr>
<tr><td>XE1008/50</td><td>50</td><td rowspan="5">High performance
Mercury free
Good mechanical properties
Water resistance</td><td rowspan="5">Electrical encapsulation
Marine
Prototyping
Protection e.g. dunnage bars</td></tr>
<tr><td>XE1008/60</td><td>60</td></tr>
<tr><td>XE1009/70</td><td>70</td></tr>
<tr><td>XE1010/80</td><td>80</td></tr>
<tr><td>XE1011/90</td><td>90</td></tr>
<tr><td>HP40/35</td><td>35</td><td rowspan="7">High performance polyester
Excellent abrasion and oil resistance</td><td rowspan="7">Concrete moulding
Rollers</td></tr>
<tr><td>HP40/45</td><td>45</td></tr>
<tr><td>HP40/55</td><td>55</td></tr>
<tr><td>HP40/65</td><td>65</td></tr>
<tr><td>HP40/75</td><td>75</td></tr>
<tr><td>HP40/85</td><td>85</td></tr>
<tr><td>HP40/95</td><td>95</td></tr>
<tr><td>E1105</td><td>30</td><td>Soft system</td><td>Soft mould making
Encapsulation
Film and TV props</td></tr>
<tr><td>E1118</td><td>10 max.</td><td>Very soft system</td><td>Gaskets and seals
Dampening
Shock absorption</td></tr>
<tr><td>XE1013</td><td>10 max.</td><td>Very soft system
Combustion modified</td><td>Gaskets and seals
Dampening
Shock absorption</td></tr>
<tr><td>E106</td><td>65</td><td>General purpose flexible system</td><td>General purpose mould making</td></tr>
<tr><td>E053</td><td>85</td><td>Thixotropic system
Good water resistance</td><td>Marine repair</td></tr>
<tr><td>DE484</td><td>85</td><td>System designed for underwater cure</td><td>Marine repair</td></tr>
</table>

Figure 2-7 provides a more general list of PU elastomer applications and suggested systems, along with indications of typical hardness. As seen in the photos, in addition to the range of properties already mentioned, cast products may be produced in a multitude of shapes and colours.

Drawing on a great variety of polymers and additives, PU elastomers lend themselves especially to innovation to address particularly difficult challenges. For example, contractors of laying under sea insulated pipelines have long sought a polyurethane specifically for use in salt water. IFS Chemicals developed a hydrolysis-resistant polyurethane which can be used as a corrosion-resistant coating, to fabricate moulded items and for pipe-jointing applications (IFS 2008).

Figure 2-7 Baxenden Ltd. – suggested PU systems for typical applications



Source: Baxenden (2008)

Like any catalyst used in PU elastomer systems, the mercury catalyst is incorporated into the polymer structure and remains in the final product. Over time – and accelerated by exposure to harsh environments, UV, abrasion, etc. – the polymer structure breaks down and mercury is released. Mercury in PU products already attracted attention some years ago. According to an investigation by the Minnesota (USA) Department of Health, some PU elastomer flooring manufactured from about 1960 through at least 1980 contained up to 0.1% mercury in phenylmercuric acetate or other organo-mercuric salts that were used as catalysts (Reiner 2005, as cited by MDH 2006). Ambient mercury concentrations in school gyms ranged from 0.13 to 2.9 µg/m^3, and in 5 of 6 gyms was above the RfC level of 0.3 µg/m^3 established by US EPA as the exposure level below which no adverse health effect is expected (MDH 2006). A separate investigation in Ohio (USA) showed that PU elastomer floors in schools also emitted mercury is excess of the 0.3 µg/m^3 RfC level (Newhouse 2003).

Key mercury catalysts

Christensen *et al.* (2004) carried out a search of the Danish National Register of Chemical Substances and Products, and discovered that about 400 products containing mercury or mercury compounds, from 25 companies, had been notified in Denmark since 1997. They found that mercury compounds were used almost exclusively in such polymer-based products as hardeners and resins for plastic materials, plastic flooring materials, jointing compounds, etc. The majority of uses involved the compound phenylmercuric neodecanoate (CAS No. 26545-49-3).

Similarly, in a submission to the UNEP Global Mercury Assessment, Finland listed six products containing phenylmercuric neodecanoate used in polymer production (UNEP 2002).

Thor Chemicals, headquartered in the UK (Margate), with manufacturing facilities in the UK, Germany, Spain and France, produces proprietary organomercury and organotin catalysts for elastomers and some foams. The catalyst registered as Thorcat 535 (CAS No. 97-1-140), in particular, is a solvent-free, low-viscous, organomercury (phenylmercuric neodecanoate) catalyst containing 35% mercury, and is said to deliver a long pot life and ambient cure (The Free Library 2008). Thor Especialidades S.A., the Spanish manufacturing facility, exported 40 tonnes of Thorcat 535 to countries outside the EU in 2006. It is estimated, based on industry sources, that 50-80 tonnes of Thorcat 535 are consumed in the EU during an average year. This catalyst supplies an estimated 70-80% of the EU market for mercury catalysts.

A web-based search revealed that the main commercial mercury compound “used as a catalyst in the manufacture of urethane” in the US is Cocure® 55, manufactured (mostly in the US, but possibly also in Belgium) by Vertellus Performance Materials, Inc. Cocure® 55 is 60-70% (by weight) phenylmercuric neodecanoate and 30-40% (by weight) neodecanoic acid (Vertellus 2008b). The total quantity of this catalyst manufactured is not public information, although significant use has been confirmed in the EU as well.

Cocure® 55 contains just under 30% mercury, is incorporated in the polyol portion of the system, and is added to the elastomer at levels of 0.4-1% (Vertellus 2008a), depending on the other components, the desired elastomer properties, etc. Consequently the mercury concentration in the polyurethane product is on the order of 0.1-0.3%.

Cocure® 55 is recommended by the manufacturer for production of polyurethane polymers and coating applications in automotive, electronic, sealant, and shoe sole end-use markets (Vertellus 2008a). Another catalyst from the same company, Cocure®44, containing 55-65% (by weight) mercury, [u-[(oxydi-2, 1-ethanediyl 1,2-benzene-dicarboxylato) (2-)]] diphenyl- is recommended for clear products such as skateboard (and presumably rollerblade) wheels and coatings (Vertellus 2008c).

Other mercury compounds (phenylmercury octoate, etc.) are also used less frequently as catalysts for different PU applications.

Total mercury consumption

It is estimated that 300-350 tonnes of mercury catalyst may be used globally in PU elastomer applications, of which some 60-105 tonnes in the EU (industry communications; SRI 2006). If one assumes the mercury catalyst is added to a system at an average of 0.5-0.6%, then approximately 55,000 - 65,000 tonnes of PU elastomers globally are catalysed with mercury each year. Assuming the global market for PU elastomers is 1.6 million tonnes, this suggests that around 4% of that global market uses mercury catalysts.

As a percentage this is not high, but it represents over 100 tonnes of mercury consumption worldwide, and 20-35 tonnes of mercury consumption with PU elastomers in the EU27+2. The mercury catalyst mainly ends up in the final product, and it is roughly estimated that the mercury consumption in PU elastomer end products corresponds to the consumption during production of 20-35 tonnes within the EU27+2.

Mercury-free alternatives
A brochure published in 2006 by a leading provider of mercury-free catalysts for PU elastomer production summarised the situation – even partly exaggerated – as follows: *"Over recent years, growing concern over the prospective toxicity of catalysts currently used, has led to renewed interest in alternative, and safer products. Noxious substances are becoming a growing issue worldwide and a total ban on mercury is expected in Europe in the near future. The presence of heavy metals in the final product has a big impact on its recyclability, preventing polyurethane based elastomers being used in certain market segments."* (Johnson-Matthey 2008)

A good example of this concern is the use of PU elastomers in undersea applications, where large quantities may be used for corrosion protection, pipe jointing, non-skid surfaces, etc. Certain customers who have long used hand-mix PU elastomers for offshore drilling applications are now putting a high priority on mercury-free alternatives. Ironically, the reason has less to do with eventual releases of mercury to the marine environment than the fact that the unused portion of the PU system (now cured) remains in the mixing barrels as hazardous waste, and especially in light of the large quantities, entails substantial costs for proper disposal.

Tin and amine catalysts are alternatives to Hg catalysts for some PU elastomer applications, titanium and zirconium compounds have been introduced for others, while bismuth, zinc, platinum, palladium, hafnium, etc., compounds are marketed for still others. In fact, known mercury-free catalysts could be used for nearly all elastomer applications, but some reduction in the key performance characteristics of activity, selectivity, catalyst lifetime, etc., may have to be accommodated until the best system is identified for a given application. (Shepherd 2008).

As suggested, a large number of Hg-free catalysts for PU elastomers have been developed as alternatives to mercury – the large number reflecting the fact that there does not appear to be a "drop-in" substitute for mercury catalysts that can be used in so many different systems, that confers similarly desirable curing properties, and that is so forgiving and easy to adjust to the needs of the user. Although titanium alkoxide catalysts, for example, provide a rapid polyurethane cure reaction, they may not provide the desirable gel time and cure profile. In many cases the system may have only a short gel time so that the polyurethane mixture tends to gel before it can be cast into its final shape. In other cases where a short gel time is acceptable, the polyurethane system may not achieve a satisfactory degree of cure within a reasonable time, resulting in finished articles that lack the necessary strength or other physical properties. A lot of research into mercury-free catalysts is going on in this sector, which is well known for frequent innovations.

Despite these challenges, it should be stressed that perfectly viable substitutes to mercury catalysts are already in use for over 95% of PU elastomer systems, and have been in use for many years.

The cost of most mercury-free catalysts is quite competitive with the typical mercury catalyst cost, and even more so if one takes account of waste disposal costs, environmental and other customer concerns. The cost of Thorcat 535 has increased significantly in recent years, and is presently in the range of €40-50/kg, compared to €25-35/kg for medium-priced mercury-free catalysts, and €10-20/kg for cheap mercury-free catalysts (IMCD 2008). A bismuth catalyst would be fairly close to the cost of Thorcat 535, while a widely used tin catalyst would be significantly less expensive (Shepherd 2008).

2.7.1.3 Uses in laboratories and the pharmaceutical industry
Mercury is used in chemical reagents for a variety of laboratory analyses and is used as a process chemical in the pharmaceutical industry for various applications.

The following uses of mercury have been described in recent reports from Member States or identified on the websites of suppliers:

Table 2-29 Examples of mercury chemicals for general laboratory use

Substance	Analysis method	Reference
Mercury II sulphate, Mercuric sulphate	COD analysis. Chemical Oxygen Demand (COD) is a measure of the theoretical oxygen consumption of a water sample. Mercuric sulphate is added to precipitate chloride ions. Different methods applies 40-400 mg of mercuric sulphate. Many industries measure COD in their process water and in water discharged from their plants, e.g. pulp and paper mills, effluent treatment plants, the chemical process industry and the food industry. Catalyst for detection of nitrogen in organic compounds using Kjeldahl method.	KemI 2004 Fisher Scientific UK, 2007
Potassium tetraiodomercurate, Mercury potassium iodide	Nessler's reagent for determination of Pseudomonas aeruginosa. Nessler's reagent contains potassium tetraiodomercurate corresponding to 0.5-0.7% of elementary mercury. Used in the food industry.	KemI 2004
Mercuric chloride	Determination of the enzyme ALAD (5-aminolaevulinic acid hydratase). PKU test to analyse specific enzymes and hormones to detect certain serious inherited diseases, including phenylketonuria. Hayem Diluting Fluid, for Erythrocyte (Red Cell) Count	KemI 2004 Cole-Parmer 2008b
Sodium amalgam	Enzyme analyses in the investigation of porphyrias.	KemI 2004

In the medicinal products sector there are special standardised analytical methods for products, raw materials, etc. In two EC Directives (2001/82/EC and 2001/83/EC) there are requirements that substances used as medicinal products in the European market shall meet the requirements of the European Pharmacopoeia, which means that they must be analysed by the methods described there. Around thirty of the analytical methods in the European Pharmacopoeia involve the use of mercury compounds as reagents (KemI 2004). They relate mainly to the determination of the mercury content of various medicinal products and raw materials, but mercury compounds are also used in other types of analysis.

A large number of buffer solutions and other chemical solutions are stabilised with 10 ppm (mg/kg) mercuric chloride (Fisher Scientific UK, 2007). The total mercury consumption for this application has not been investigated further, but may be significant.

Mercury standards are used for calibration of analysis of mercury and mercury compounds in different media.

Mercury consumption

The Swedish Chemicals Inspectorate estimated that the quantities of mercury compounds used in the form of analytical chemicals in Sweden in 2003 correspond to about 53 kg of mercury of which 14 kg was used for COD analyses in vials (KemI 2004). In Denmark the use of mercury with laboratory chemicals has decreased from about 510 kg/year in 1982/83 to 20-40 kg/year in 2001 (Christensen *et al.*, 2003), of this COD analysis is estimated to account for 70%. In Norway 37 kg mercury was used for laboratory analysis in 2005 (Norway, questionnaire response).

The COD analysis represented in France the major mercury use with laboratory chemicals and it is reported that about 900 kg mercury was annually used for this analysis method in the late 1990s (AGHTM 2000; Lestel 2004).

Floyd *et al.* (2002) roughly estimated that 100-200 kg of mercury is used in chemical agents and hospital laboratory reagents in the EU (15) around year 2000 which seems to be too low considering the reported consumption in Sweden and Denmark and the data obtained from chemical suppliers.

Using the Danish, Swedish and Norwegian data and assuming the same per capita consumption in other countries would give an EU27 total of 2.5-3 tonnes mercury for laboratory use. It is, however, difficult to extrapolate from those small countries as regards the use in the pharmaceutical industry as the mercury compounds are maybe used mainly in some specific industries.

Suppliers of mercury chemicals estimate the total EU-wide annual consumption of chemicals used in laboratories and the pharmaceutical industry as follows (only major uses mentioned, see Table 2-27 for more details): mercuric sulphate 100-500 kg, mercury-II-thiocyanoate 100-500kg, mercuric potassium iodide 10-100 kg, ammoniated mercury 100-500kg. Further a part of mercury-I-chloride (total 5-15 tonnes), mercury-II-chloride (>15 tonnes) and mercury-II-oxide (total 5-15 tonnes) may be used in laboratories and the pharmaceutical industry. In general, the use of mercury compounds in the pharmaceutical industry is not well understood, and only some very rough estimates on the mercury use can be given.

Based on the available information it is estimated that the EU27 consumption of mercury with laboratory chemicals and in the pharmaceutical industry is 3-10 tonnes.

Alternatives

As part of the preparations for the Swedish mercury ban, the Swedish Chemicals Inspectorate, KemI investigated in 2004 alternatives to mercury in laboratory reagents. KemI judged that the mercury use can be phased out in most of the applications, given time for the development and testing of alternative methods. For some areas a special need for exemptions from the general ban was identified, as follows:

- Analysis of mercury. Mercury is an element that will always need to be monitored as regards its occurrence and residue levels.
- Analysis in the medicinal products sector. In the medicinal products sector there are specific standardised analytical methods for products, raw materials, etc, which are collected in pharmacopoeias.
- Chemical oxygen demand (COD). For most applications there are mercury-free alternative methods, but a transitional period is necessary from both technical and in certain cases economic points of view.

Three alternatives to chemical oxygen demand (COD) using mercuric sulphate are available:

- COD without the addition of mercuric sulphate. It is possible to measure COD without adding mercuric sulphate if the sample does not contain too many chloride ions. COD can also be determined using potassium permanganate as the oxidising agent: in this case mercuric sulphate is not added. This analysis is often designated CODMn or permanganate number and is suitable for measurements on water with a low content of organic matter, such as lake water, since the detection limit is lower than for COD with potassium dichromate.

- TOC analysis. Total organic carbon, TOC analysis gives a measure of the quantity of organically bound carbon in the sample, both dissolved and in the form of particles. The analysis is sensitive to particles in the sample and the sample can then be filtered before analysis. If filtration is carried out before analysis of TOC only the fraction of the organic matter dissolved in the water is measured. This analysis is often called Dissolved Organic Carbon (DOC). It is possible to make correlations between COD and TOC by measuring the parameters in parallel over a period.

- BOD. Biochemical oxygen demand (BOD) is an analytical method that measures the quantity of oxygen consumed bio-chemically under controlled conditions in a specified time.

The Waste Water Directive 91/271/EEC states that COD must be measured, but not that the method using mercuric sulphate must be used.

2.7.1.4 Preservative in vaccines and eye/nasal products

Thimerosal (or thiomersal, 2-mercapto-benzoic acid) is a organomercuric preservative mainly used in vaccines and some eye/nasal medical products. The compound contain 49.6% mercury.

Thimerosal has also been reported as used in immunoglobulins, but no evidence of the use of thimerosal in the EU has been obtained. It is reported that in the USA thimerosal has been discontinued for most uses in plasma derived products (U.S. FDA 2004)

From a mercury mass flow perspective the use of mercury for this application is relatively small, but the possible health effect of the use of thimerosal in vaccines has raised a significant controversy. In 2006 the WHO Global Advisory Committee on Vaccine Safety (GACVS) concludes that there is no evidence of toxicity in infants, children or adults exposed to thiomersal (containing ethyl mercury) in vaccines (GACVS 2006). However, WHO continues to review the evidence for preterm and malnourished infants (WHO 2007).

In vaccines the primary purpose is to prevent microbial growth in the product during storage and use. For this purpose thimerosal is added to the final product. In some vaccines (i.e.: whole cell pertussis vaccine), the thimerosal is further used for the inactivation of both microorganisms and toxins together with other methods (EVM 2008).

The maximum quantity of thimerosal used in multidose vaccines does not exceed 50 µg per dose. For all non-live attenuated vaccines formulated in multidose presentations, it is mandatory to add a preservative that meets the criteria of the Pharmacopoeia and thimerosal is widely used for this purpose. Multidose vaccines are mainly used in developing countries for storage and logistic reasons (e.g., cold chain distribution). Single-dose vials require significantly larger cold space storage as well as increased transport needs, which is currently not feasible in many developing countries (EVM 2008).

Besides the use in multidose vaccines for developing countries, thimerosal is also used for vaccines for influenza pre-pandemic and pandemic preparedness as multidose presentations according to the vaccine manufacturers are critical for these vaccines allowing manufacturers to deliver the volumes of vaccines necessary (EVM 2008).

Most of the vaccines delivered in Europe are in single doses, and do not contain thimerosal as a preservative. Some vaccines contain traces of thimerosal, as it is used during the manufacturing process.

Thimerosal is not manufactured in Europe but imported from a single Argentinean producer.

The total quantity of thimerosal imported by members of European Vaccine Manufacturers (EVM) is less than 0.25 tonne per year corresponding to 0.125 tonnes of mercury (EVM 2008). A significant part of this is used for vaccines exported to developing countries.

Marketing of mercury compounds in cosmetics is prohibited in EU by Directive 76/768 (with amendments) except for phenyl mercuric salts and thimerosal for conservation of eye makeup and products for removal of eye makeup in concentrations not exceeding 0.007 percent (weight-to-weight) mercury.

The total EU-wide consumption of thimerosal as preservative in vaccines (for vaccines used in the EU) and eye make-up products is estimated at 0.2-1 tonnes (0.1-0.5 tonnes mercury), based on information from suppliers of mercury chemicals

2.7.1.5 Preservatives and fungicides in water-based paint

Mercury compounds have historically been widely used as preservatives and fungicides, in particular in water-based paint. The application is today regulated by the Biocide Directive 98/8.

Pursuant to Directive 98/8/EC, Member States may only authorise the placing on the market of biocidal products containing active substances included in Annex I, IA or IB to that Directive. No mercury-containing compounds are included in the Annex, and in fact there are still very few substances included in the annex. However, there is also no mercury compound included in the list of existing active substances for which a decision of non-inclusion into Annex I or Ia of Directive 98/8/EC has been adopted (EC 2007a).

Under the transitional measures provided for in the Biocide Directive, Member States may allow the placing on the market of biocidal products containing active substances not listed in Annex I, IA or IB which were already on the market on 14 May 2000. Pursuant to that Directive a 10-year programme of work is to be carried out for the review of all existing active substances. No mercury-containing products are included in the list of substances covered by the review programme (EC 2007b).

Mercury compounds are prohibited in preparations intended for use (a) to prevent the fouling by micro-organisms, plants or animals; (b) in the preservation of wood; (c) in the impregnation of heavy-duty industrial textiles and yarn intended for their manufacture; and (d) in the treatment of industrial waters, irrespective of their use (8^{th} amendment to Directive 76/769/EEC).

This means that a Member State in the transition period may allow the placing on the market of a mercury compound for other biocidal applications.

It is reported that in total 6.4 tonnes of mercury-containing biocides were used for manufacturing of water based paints in Italy, broken down into 2.0 tonnes phenylmercury acetate and 4.4 tonnes phenylmercuric 2-ethylhexanoate (Italy, questionnaire response 2008). According to the Material Safety Data Sheet (MSDS) from a major supplier, the content of phenylmercuric acetate in the commercial product is 98%. With a mercury content of the compound of 60% the 2 tonnes correspond to 1.2 tonnes mercury. It has not been possible to identify MSDS from suppliers of phenylmercuric 2-ethylhexanoate. Assuming a similar situation to phenylmercuric acetate since the end use is similar, and the mercury content of the compound phenylmercuric 2-ethylhexanoate is about 58%, this use in Italy may imply nearly 2.6 tonnes mercury. The total consumption of mercury for production of paints in Italy thus appears to be at least 3.5 tonnes in 2006.

Phenylmercuric acetate has in the literature been reported to be used as preservative in other aqueous solutions like inks, adhesives and caulking compounds, but it has not been possible to confirm any EU use of the compound for these applications.

It is estimated by major suppliers of mercury chemicals that in total 20-40 tonnes (12-24 tonnes mercury) of phenylmercuric acetate was used EU-wide primarily for fungal control or as a catalyst in the production of polyurethane elastomers, but it is not indicated how much of this was used for fungal control.

On this basis, and considering input from industry contacts, the EU-wide consumption of mercury with preservatives in water-based paints is estimated at 4-10 tonnes mercury.

Alternatives
Biocides are used in water based paints for two reasons: as in-can preservatives for preservation of the paint on the shelf and as film preservatives for preservation of topcoat paints used for outdoor applications by the control of microbial (mainly fungal) deterioration of the paint film. A number of organic compounds are used as preservatives in paints. A survey of the use of pesticides in Denmark revealed that the most common in-can preservatives for paints manufactured in Denmark was Bronopol, BIT and CIT/MIT (trivial names) while the most common film preservatives were folpet and dichlorfluanide (Lassen *et al.* 2001). Mercury compounds has most probably been replaced by other biocides in most Member States.

2.7.1.6 Disinfectants

Disinfectants are, like preservatives, covered by the Biocide Directive and the discussion regarding preservatives in paint above also applies to mercury compounds used as disinfectants (apart from disinfectants used in cosmetics). Traditionally a number of mercury compounds have been used as disinfectants including mercurochrome (Merbromin), thimerosal (Merthiolate), mercury iodide, mercury oxycyanide, and mercury-II-chloride.

According to information from chemical suppliers some 2-4 tonnes mercurochrome (0.5-1.0 tonne mercury) is used annually in the EU as disinfectant and in the pharmaceutical industry. Among other suppliers of the compound or a final product, Merbromin 2% solution for export is manufactured by Alfa Intes (2008), Italy. These and other exports from the EU are considered to be included in the 2-4 tonnes indicated by the chemical suppliers.

Thimerosal, especially under the name of Merthiolate, was widely used in the past as a topical disinfectant, and likely continues to be used as such in many parts of the world. It is reported in Sweden to be used to disinfect certain medical equipment used, for example, in the case of transfusions and dialysis. This is sophisticated equipment that according to the Swedish Chemicals Inspectorate is used rarely and is only to be found in a few hospitals in the country. One clinic for transfusion medicine states that 29 g of thimerosal was used in 2003 in the case of transfusion equipment and for dialysis equipment a further 40 g was used (KemI 2004). Thimerosal is probably also used for disinfection of medical equipment in other countries.

A large part of the global production of thimerosal (possibly up to 5 tonnes) takes place in Argentina and is used in all parts of the world. Much of this trade occurs via the EU. Therefore, thimerosal exports from the EU are considered to be significant, but they are primarily re-exports of imported thimerosal. There is no breakdown between thimerosal use as a preservative and its use as a disinfectant, although indications are that its use as a disinfectant is predominant (industry contacts). Information from chemical suppliers indicates the EU consumption of thimerosal at 100-500 kg, containing 0.05-0.25 tonnes of mercury.

Mercuric iodide is according to information from chemical suppliers marketed in the EU in volumes of 0.1-0.5 tonnes (0.06-0.3 tonnes mercury) for use as disinfectant in soaps. Mercury in soaps marketed in the EU are banned by Council Directive 76/768/EEC, but the soap (or the mercury compound) may be exported. Export of "cosmetic" soaps containing mercury is banned by Regulation 304/2003, but the regulation does not mention export of "antiseptic" soaps. The actual end use of the antiseptic soap has not been investigated further. EU exports of mercuric iodide as a compound are not considered to be significant.

Mercury oxycyanide is indicated by chemical suppliers to be marketed for use as a disinfectant in quantities of <10 kg per year. The actual application has not been investigated further.

Based on the available information, but assuming it is not complete, it is roughly estimated that the total mercury consumption for disinfectants in the EU, including products produced in the EU for export, is 1-2 tonnes mercury.

Alternatives

A large number of mercury-free compounds and procedures are available for disinfection. Hence alternatives for the specific uses of mercury disinfectants have not been investigated further.

2.7.1.7 Pigments

The pigment vermillion or cinnabar (mercuric sulphide, HgS) has been used since prehistory as a red colour for paint and fabric dye. The term vermillion or cinnabar is often designated to a pigment to indicate the colour although the pigment does not comprise mercuric sulphide. Vermillion seems to be used in limited amounts e.g. for restoration work or as artistic colour. Vermillion is e.g. available from Kremer Pigmente, Germany (2007), a company specialised in products used for restoration work and art. Cinnabar pigment, based on mercury sulphide from China, is marketed for use in oil, tempera, water colours/gouache or lime/fresco in the series of "historical pigments". The French pigment manufacturer SLMC, France, is in the literature specifically indicated as manufacturer of mercury pigments, but the company does not produce mercury pigments today. The total quantity is assumed to be small and has not been investigated further.

2.7.1.8 Other applications

Skin lightening soaps. The marketing of mercury-containing soaps in the EU is regulated by Directive 76/768 (with amendments) while the export of the soaps is prohibited by Regulation (EC) No 304/2003 concerning the export and import of dangerous chemicals (with amendments). While there is a significant segment of the EU population that uses skin lightening preparations, the illegal import of skin lightening soaps most likely takes place in limited quantities. From Sweden it is reported that skin lightening soaps have been found occasionally at inspections (Sweden, questionnaire response 2008).

Mining. Romania report (stakeholder consultation 2005) that 0.2 tonnes mercury compounds are used in mining production, not specified further. From this amount 80% is being recovered by regeneration in the process and reintroduced into the technological process.

Fireworks. In the literature the use of mercury chloride as chloride donor in fireworks is described. A Swedish study states that mercury is not used in the modern manufacturing of fireworks, and that it was only possible to find trace levels of mercury in assays of six selected types of firework (Göteborgs Miljöförvaltning, 1999). The European Standards of the EN 14035 series on fireworks (currently comprising 38 standards) specifies that mercury shall not be present in fireworks.

Mercury fulminate detonator. Mercury fulminate has historically been used as a detonator for other explosives. According to Floyd *et al.* (2002), mercury fulminate was apparently no longer manufactured in the EU around 2000. No data on EU production of mercury fulminate is available from the chemical databases of the European Chemicals Bureau. According to information from suppliers of mercury chemicals, mercury fulminate is most probably not used in the EU today.

Pesticides. Pesticides containing mercury are prohibited by the Plant Protection Products Directive 79/117/ECC. Commission Directive 91/188/EEC deleted some limited exemptions from these restrictions which had previously been allowed. However, there is compelling evidence that stockpiles of old pesticides containing mercury compounds still exist in the EU (Netherlands input to Stakeholder consultation and others)

Tanning and preparation of felt. Mercury has in the literature been mentioned for use in tanning and preparation of felt. Mercury nitrate was historically used in processing the animal hair that was used in making felt. It caused the fibres of the fur to separate from the pelt and to mat together more readily. This application is the background for the well known hatter story and the expression "mad as a hatter".

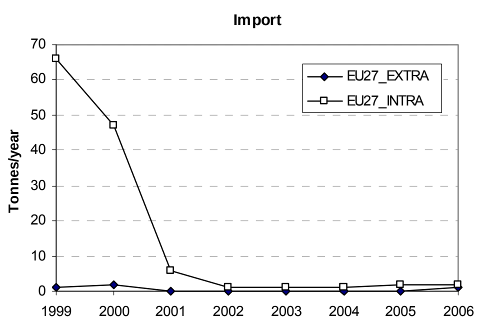
Flanders report in their questionnaire response that sites exist in Flanders contaminated by mercury from the tanning industry. In the 18^{th} and 19^{th} century mercury nitrate was used to soak off the hair of rabbit skin, but the production of the mercury preparation was discontinued in the 1970s.

No current consumption for preparation of felt have been identified.

2.7.2 Current mercury consumption and trade

The only mercury compound specifically identified in recent trade statistics is mercuric oxide. Import/export data by country is shown in Annex 5. The data shows a decreasing trend in the export of mercury oxides from Germany and Spain, while a few high export figures for the Netherlands and Belgium for one or two years introduce substantial noise into the overall trend as indicated in the figure below. These trade statistics are therefore of limited value for understanding the trade and use of mercury compounds within the EU.

The researchers did reveal, however, a significant use of mercuric oxide in the EU for the production of battery components, as described in section 2.3.



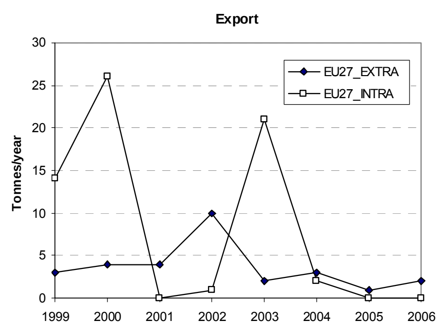


Figure 2-8 Import and export of mercury oxides between EU Member States (EU27_intra) and between EU Member States and Non-EU countries (EU27_extra)

A partial cross-check of industry estimates regarding EU production, import and export of mercury compounds was obtained through documentation on EU exports as notified in accordance with Regulation (EC) 304/2003 implementing the Rotterdam Convention on Prior Informed Consent (PIC), which obliges EU exporters to register all exports of mercury compounds outside the EU. This documentation confirms that the main EU exporters of mercury compounds are located in Spain and Germany, which reflect as well the locations of the main production facilities.

The following table, summarising information from a majority (though not all) of the EU Member States, suggests that the number of countries importing mercury compounds from the EU is gradually increasing, as is the quantity of compounds exported from the EU. These trends are further reflected in the number of notifications filed every year:

- 7 notifications in 2003,
- 23 notifications in 2004,
- 33 notifications in 2005,
- 42 notifications in 2006,
- 54 notifications in 2007 and
- 80-100 notifications estimated for 2008 on the basis of initial filings January - March.

Table 2-30 Exports of mercury compounds listed in Annex 5 to Regulation (EC) 304/2003 to various geographical regions on the basis of information submitted by reporting Member States to the Commission (EC 2008)

Year	Number of importing countries	Quantity (tonnes)	Breakdown by broad geographic region *1				
			AF	AP	CEE	LAC	WEOG
2006	57	104.69	8.90	75.15	1.89	7.05	11.70
2005	35	63.37	5.51	37.81	0.23	4.70	15.12
2004	41	76	6	45	1	4	20

*1 The breakdown of the exported quantities (in tonnes) is reported by broad geographic region, using the 5 UN regions: Africa (AF), Asian and Pacific States (AP), Central and Eastern Europe States (CEE), Latin American and Caribbean States (LAC) and Western Europe and other States (WEOG).

The total EU-wide mercury consumption in compounds not included in other chapters is estimated at 28-60 tonnes. A summary of the consumption by application area is shown in Table 2-31. It should be noted that a part of the mercury in "chemical intermediate and catalyst (except PU)" may be used for production of other compounds and in fact double accounted, so the total is somewhat lower.

EU "consumption" should be roughly equivalent to *Imports* plus *EU production* less *Exports*. Figures regarding EU compound production (70-100 tonnes mercury), exports (55-75 tonnes mercury), and imports (15-35 tonnes mercury), are best estimates based on input from various industry contacts, PIC notifications, etc.

Table 2-31 Mercury consumption with chemicals in EU in 2007 not included in other sections

Application	Estimated Hg content of compounds consumed in EU Tonnes Hg/year	Comments
Chemical intermediate or catalyst (except PU) *1	10 - 20	
PU catalyst	20 - 35	Indicates the amount of mercury in PU in products used within the EU. The use for production of PU elastomers in the EU is estimated to be lower
Laboratories & pharmaceutical industry	3 - 10	not including use of Hg compounds as a chemical intermediate
Preservatives in vaccines and eyes/nasal products	0.1 - 0.5	
Preservatives in paints	4 - 10	
Disinfectant	1 -2	
Pigments	<1	
Other applications	<1	
Total (round) *1	28 - 60	Note that these are compounds not included elsewhere in the analysis

*1 The use as chemical intermediate is not included in the total in order to avoid double counting

2.7.3 Mercury accumulated in society

PU elastomers

PU elastomers are used for may types of products: vehicle parts, shoes, electronics, sealants. etc. The total mercury content of these products in society is roughly estimated by assuming that the products on average last for 10 years and the amount brought into society with various products has been on the 2007 level of 20-35 tonnes for the last ten years. Due to the gradually decreasing use of mercury in an expanding market, it would be reasonable to assume that the demand for mercury in this sector has been relatively stable for the concerned period. On this basis the total accumulated amount is estimated at 275 tonnes as the best estimate.

Mercury preservatives in paints

The half-life of mercury in water-based paints has been estimated to be about 1 year i.e. that half of the mercury content is released each year (NJMTF, 2002). Assuming a annual consumption 4-10 tonnes mercury for this application, the accumulated amount is estimated at 14 tonnes.

Laboratory chemicals

Surveys of mercury on the shelves of laboratories has revealed significant amounts stored in mercury chemicals and mercury metals. This is further discussed in section 3.1.4.1 and mercury compounds stored in laboratories are included in the estimates provided in that section.

Mercury pigment

Mercury pigments are used in very limited amounts in paints for artwork and restoration work. No data on the historic consumption of mercury pigments in the EU has been identified, but mercury pigments has most probably only been used in very small quantities for many years. In the USA it has been estimated that the total mercury content of pigments in the waste stream would decrease from 29.3 tonnes in 1970 to 1.4 tonnes in 2000 (OECD 1993). It is roughly estimated that the total quantity of mercury accumulated in pigments in the EU is not more than 10 tonnes.

Summary
The accumulated quantities of mercury due to other uses of mercury chemicals than mentioned above is estimated to be insignificant and the total accumulated amount of mercury in products in society in this product category is estimated at 300 tonnes.

2.7.4 Mercury-free alternatives

Table 2-32 summarises information on marketed alternatives for mercury-containing products known to be marketed within the EU today. For other applications, for which no evidence of mercury-containing products marketed today has been obtained, it is deemed that suitable alternatives are readily available on the EU market.

The indicated substitution level is based on information on substitution level provided by Member States (see Annex 1) supplemented by an assessment made by the authors. A range indicates that different substitution levels are reached in different Member States.

Table 2-32 Overview of alternatives to mercury-containing chemicals marketed in the EU

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury thermometers	Substitution level	Remarks
Mercury catalysts for PU elastomer production	Tin and amine catalysts are alternatives to Hg catalysts for some PU elastomer applications, titanium and zirconium compounds have been introduced for others, while bismuth, zinc, platinum, palladium, hafnium, etc., compounds are marketed for still others	=	3	The substitution level may be different for different PU elastomer applications
Mercury II sulphate for COD analysis	COD without the addition of mercuric sulphate; TOC analysis; Biochemical oxygen demand (BOD) analyses	N	2-3	
Chemical reactants for other reagents e.g. Nessler's reagent, Hayem Diluting Fluid and others	Not investigated	N	2-3	
Thimerosal in vaccines	Not investigated	N	2-4	Replaced by other preservatives in many vaccines
Thimerosal for preservation of eye make up products	Not investigated	N	3-4	
Mercury compounds used as disinfectants	A number of organic compounds	N	3-4	
Biocides in paint	A large number of organic compounds	=	3-4	
Pigment (vermilion, HgS)	Organic and inorganic pigments	=	4	Used for restoration work, where specific colour is

Key assigned to the overall current user/consumer price levels for mercury-free alternatives as compared to mercury technology:
– Lower price level (the alternative is cheaper)
= About the same price level
\+ Higher price level
++ Significant higher price levels (more than 5 times higher)
N Not enough data to assign an indicator

Key to assigned substitution level indices:
0 No substitution indicated in assessed data sources; development often underway
1 Alternatives are in commercial maturation, or are present on the market but with marginal market shares
2 Alternatives are commercially matured and have significant market shares, but do not dominate the market
3 Alternatives dominate the market, but new products with mercury also have significant market shares
4 Mercury use is fully, or almost fully, substituted
N Not enough data found to assign an indicator
? Indicator very uncertain due to limited data

2.7.5 Producers of mercury compounds and alternatives

As in many other sectors of the chemical industry, this is a sector of change and consolidation. There are companies like Minas de Almadén that was once one of the largest producers of compounds, but now deals only with metallic mercury. Facing the realities of low-cost production in other countries, Acros Organics in Belgium no longer produces its own chemicals, but has expanded its role as a distributor. Scharlab, near Barcelona, and Chemos, near Regensburg, continue to manufacture compounds, but have increasingly specialised in specialty chemicals. Omicron, also in Barcelona, has changed owners and focus more than once in recent years, and now manufactures bismuth salts in the EU, while all mercury compounds are now produced through a subsidiary in India.

The following list of manufacturers and distributors of mercury compounds and alternatives in the EU is based on Member State responses to the questionnaire, internet searches and contact with market players. As there are hundreds of players in this market, the list is not comprehensive, but includes major players with regard to these applications.

Country	Company name	EU producer	Supplier of:					
			Compounds and intermediates		Catalysts		Lab chemicals	
			Hg	Hg-free	Hg	Hg-free	Hg	Hg-free
BE	Acros Organics BVBA		X	X	X	X	X	X
CZ	Bome sro		X				X	X
DE	CFM Oskar Tropitzsch eK		X	X	X	X	X	X
DE	Chemos GmbH	X	X	X	X	X	X	X
DE	Fox Chemicals	X	X	X	X	X	X	X
ES	Gomensoro SA	X	X	X	X	X	X	X
UK	Johnson-Matthey Ltd	X	X	X	X	X	X	X
ES	Panreac Quimica SAU	X	X	X	X	X	X	X
DE	Scharlab SL	X	X	X	X	X	X	X
DE	Sigma Aldrich Chemie GmbH	X	X	X			X	X
UK	Thor Group Ltd.	X	X	X	X	X	X	X
BE	Vertellus Chemicals SA		X	X	X	X	X	X

A large number of producers of polyurethane elastomers in the EU may use mercury catalysts that ends up in the products, and these producers may consequently be considered producers of mercury-containing products. It was beyond the scope of the current study to identify PU producers using mercury catalysts.

2.7.6 Collection and treatment of waste

Very limited information on the collection and treatment of waste of mercury chemicals have been available for this study.

Mercury chemicals used in laboratories must be expected to a large extent to be collected and disposed of as hazardous waste. In the European waste catalogue the waste category “16 05 06 laboratory chemicals, consisting of or containing dangerous substances, including mixtures of laboratory chemicals" covers this waste. The mercury-containing laboratory chemicals are in many countries disposed of separately e.g. in Denmark in 2001 the hazardous waste treatment plant, Kommunekemi received 12 tonnes liquid from COD analysis and 11 tonnes liquid from Kjeldahl analysis (Christensen *et al.* 2004). The wastes was disposed of in a hazardous waste deposits. It is for the purpose of this analysis roughly estimated that 50% of the 3 - 10 tonnes used in laboratories and pharmaceutical industry is disposed of for recovery and the remaining 50% disposed of as hazardous waste for deposits.

Products of polyurethane elastomers are expected generally to be disposed of with the municipal waste stream. A part of the elastomers, e.g. from vehicles shredder waste will be disposed of to special dump sites. It is roughly estimated that the amount disposed of correspond to the actual consumption and that 80% of the 20-35 tonnes is disposed of with MSW and the remaining 20% goes for special waste dumps.

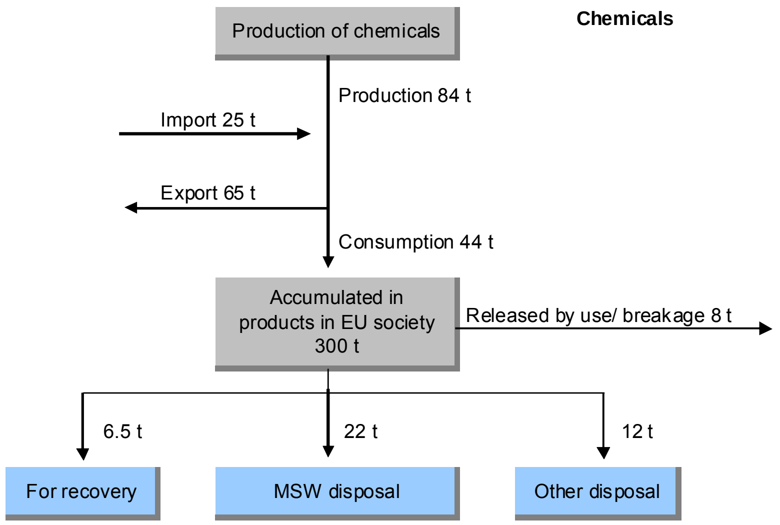
Mercury in preservatives in paints and in disinfectants and other applications as preservative is estimated mainly to be released to the environment either by direct emissions to the air or via wastewater treatment.

2.7.7 Data gaps

The details of most uses of mercury chemicals as catalysts and intermediates in the pharmaceutical and chemical industries are not known.

2.7.8 Mercury mass balance

The data obtained on the flows of mercury in chemicals are summarised in the flowchart below.



2.8 Miscellaneous uses

2.8.1 Applications of mercury and alternatives

Mercury is used for a number of miscellaneous applications.

This section includes the following applications for which there is evidence that mercury is used today in new products marketed in the EU:

- Mercury metal for porosimetry and pycnometry;
- Calibration of mercury monitors;
- Mercury triple point cells for thermometer calibration;
- Mercury-cadmium-telluride (MCT) in infrared light detectors;
- Conductors in seam welding machines;
- Mercury slip rings;
- Mercury in plasma display panels;
- Fire gilding;
- Mercury pendulums;
- Elbow shock absorber wristband;
- Folklore medicine;
- Ethnic/cultural/ritualistic uses and.

For two miscellaneous applications, mercury is used for maintaining of products already in circulation in society and the applications may add significantly to the pool of mercury in accumulated in society (mercury may also be used for maintaining some measuring equipment mentioned in other sections)

- Lighthouses (lens floating in mercury);
- Mercury in large bearings of rotating mechanical part in, for example, older wastewater treatment plants.

For one banned application of mercury, evidence exist of illegal use of mercury within the EU:

- Gold extraction using mercury (in French Guiana);

For a number of applications, evidence has been obtained on the marketing of mercury-containing products in the USA or Canada today, but it has not been possible to find any evidence as to the marketing of these products in the EU. It cannot be ruled out that some of these products find its way to the EU market:

- Esophageal dilators and gastrointestinal tubes with Hg;
- Recoil suppressor for rifles and shotguns;
- Vacuum pumps with mercury;
- Tire balancers;

For two applications it is known that mercury is used in a number of installations worldwide, and it is expected that mercury will be used for this application in the future in the EU:

- Liquid mirror telescopes;
- Target in spallation neutron sources;

For some applications of mercury described in the literature it has not been possible to find any evidence on present use of mercury in products marketed in the EU or other western countries. It cannot be ruled out that some products may find their way to the EU market, but it is estimated that the total volume of mercury with those products will be insignificant.

The applications include:

- Toys, novelties or games;
- Browning and etching steel.

2.8.1.1 Porosimetry and pycnometry

Mercury porosimetry and pycnometry and two measurement methods for characterization of pore structure of materials that take advantage of the property that mercury at atmospheric pressure will not enter pores smaller than 15 microns in diameter. The two methods may be used in conjunction with other methods for pore structure characterization like porometry and permeametry.

The options for reducing mercury input for porosimetry are assessed in chapter 6 and for this reason the current section includes a relatively detailed description of the use of mercury for this application as input for the analysis of policy options.

Porosimetry

Porosimeters are used for measurements of porosity which is a measure of the void spaces in a material. The operation of all mercury porosimeters is based upon the physical principle that a nonreactive, non-wetting liquid will not penetrate fine pores until sufficient pressure is applied to force its entry. Monitoring mercury volume intruded as a function of pressure permits the generation of pore size/volume distributions (Quantachrome 2007). Mercury porosimeters are typically applied for materials with pore diameters in the range of 0.0036 µm to >950 µm.

Porosimeters have for decades served quality control and research needs for characterization of materials such as catalysts, surgical implants, electrodes, ceramics and sintered metals, pharmaceuticals (e.g. in-situ drug delivery systems), filtration media and membranes, mite-resistant textiles and many others.

According to a major UK supplier, mercury porosimeters are used by several hundreds of companies and research institutions in the UK. In Denmark porosimeters are used by 5-6 companies or institutions, in Sweden it is estimated that less than 30 porosimeters are in use (Swedish Chemicals Inspectorate 2008). The contacted producers of porosimeters have reported quite different estimates of total number of working porosimeters in Europe (300-10,000 units) converging - in our judgement - on a most probable range of some 1000-2000 units. Assuming a technical life of 10-15 years, we roughly estimate the annual market at a couple of hundred porosimeters.

According to the manual for a porosimeter from Micromeritics, approximately 10 pounds (5 kg) of triple-distilled mercury as a minimum is required for installation of the meter (Micromeritics 2001). The mercury is in fact not an integral part of the meter, but is used in the analysis. Typically around 3.4-5 ml (45-65 g) mercury is used per analysis (range from 1 to 20 ml), of which some is pressed into the sample, and the rest is contaminated by the hydraulic oil used as the medium for the high pressures involved. Both sample and used free mercury are recycled or discarded after the analysis.

Data on consumption of mercury for porosimetry from instrument manufacturers vary extensively, and are also reported as very uncertain. The Danish Research Institute RISØ has confirmed that they annually use about 30 kg mercury for porosimetry on 750 analyses (40 g per analysis). The porosimeter is used in fuel cell research. According to a Danish supplier of porosimeters the users of the equipment in Denmark typically consume from 12 to 240 kg mercury annually. Two manufacturers of porosimeters considered 10-200 kg Hg/year a probable range for mercury consumption per porosimeter. One other manufacturer stated a likely average of 10 kg/year, and a fourth manufacturer provided indications of probable sample frequency and consumption per analysis that suggest possible consumption in the very high end of the 10-200 kg/y range. In Sweden it is reported that the porosimeters typically contain 2 kg mercury each and the mercury is replaced every 10 years, corresponding to an annual consumption of only 0.2 kg per porosimeter per year (Swedish Chemicals Inspectorate 2008). The continuous use of mercury for the measurements may, however, have been overseen.

One producer of mercury intrusion porosimetry instruments exist in Italy, Thermo Fisher Scientific (formerly Carlo Elba Sp.A; or CE Instruments). The European market seems to be dominated by equipment from three companies in the USA: Micromeritics, Quantachrome, Porous Materials Inc., besides Thermo Fisher Scientific, Italy.

On the basis of the available information presented above it is roughly estimated that some 10-100 tonnes of mercury is used annually in the EU27+2, assuming that 1000-2000 units on average use some 10-50 kg per year.

While releases of mercury likely occur to the atmosphere, and perhaps to waste water, during the analysis procedure, these are very hard to quantify without more detailed information of the prevalence of release reduction equipment and safety procedures in the relevant laboratories in EU Member states. Most of the mercury losses are however expected to follow mercury-saturated sample wastes from the analyses; waste which is mainly expected to be recycled or disposed of at hazardous waste landfills.

Pycnometry
A mercury pycnometer provides the user with a measurement of bulk density of a material. As described by a supplier of mercury pycnometers, mercury pycnometry is a volume displacement technique based on the fact that mercury at atmospheric pressure will not enter pores smaller than 15 microns in diameter. By determining the weight of the sample chamber with and without mercury, the density of mercury (known), and the weight of the sample, one can determine the difference in the volume of mercury in the sample chamber with and without the sample present. The difference in the volume of mercury is the volume of the sample. Since one knows the weight of the sample, and has determined the bulk volume, the bulk density can be deduced (Porous Materials 2008e). According to the manufacturer, the primary use of the mercury pycnometer is quality control in industries ranging from batteries to nonwovens and pharmaceuticals. Specific examples include the bulk density test of electrode powders and green ceramics. It has not been possible to identify any European manufacturers of mercury pycnometers. Mercury pycnometers are manufactured by Porous Materials Inc. in the USA and marketed in Europe by PMIAPP Europe (2008).

According to a manual of operating and maintaining a mercury pycnometer, the mercury used for the measurements is cleaned and dried and returned to the reservoir of the meter (CISM 2004). The total mercury consumption for pycnometry has not been investigated further but is estimated to be small compared to the consumption for porosimetry as the mercury is not ending up in the specimens.

EXAMPLE:

"The PoreMaster consists of three automatic mercury intrusion porosimeters offering new concepts in automated pore size analysis. The PoreMaster 33 porosimeter achieves a maximum pressure of 33,000 psia for pore size measurements in the range from over 950 micron to 0.0064 micron pore diameter. Two low pressure stations plus one high pressure station."

Manufacturer: Quantachrome Instruments, USA

Source: http://www.quantachrome.co.uk/page14.html

Alternatives

Two alternatives to mercury intrusion porosimetry have been identified:

- Mercury-free extrusion porosimetry;
- Mercury-free intrusion porosimetry.

Mercury-free liquid extrusion porosimetry applies a different principle than the intrusion porosimetry. Whereas the intrusion methodology measures the pressure needed for the intrusion of the liquid into the sample, the extrusion porosimetry measure the porosity of the material by the pressure needed for pressing a wetting liquid that spontaneously has filled the pores out of the material. (Jena and Gupta 2002; Gupta and Akshaya 2001). Liquid extrusion porosimeters for measuring porosity in the pore diameter range of 0.06 µm to 1000 µm, are commercially available from Porous Materials Inc. USA (Porous Materials 2008a), pores sizes below that range are difficult to measure with the method. The extrusion method requires that one side of the sample is plane. This means that measurements on samples, where the preservation of the original form is important, cannot be measured with the method. The properties measured by the extrusion porosimetry are not exactly the same as the properties measured by the mercury porosimetry, and extrusion porosimeters are not readily applicable for all applications of mercury porosimetry. Advantages of liquid extrusion porosimetry compared to mercury intrusion porosimetry according to the producer of liquid extrusion porosimeters are shown in Table 2-33 while a comparison of characteristics of mercury porosimetry, liquid extrusion porosimetry and water intrusion porosimetry is shown in Table 2-33.

Table 2-33 Advantages of liquid extrusion porosimetry compared to mercury intrusion porosimetry according to the producer of liquid extrusion porosimeter (Porous Materials 2008b)

Liquid extrusion porosimetry	Mercury intrusion porosimetry
No toxic substances	Mercury used
Low test pressure and negligible structural distortion	An order of magnitude higher test pressure and appreciable structural distortion
Sample reusable	Sample discarded
Liquid permeability measurable	Permeability net measurable
Only through pores measurable	Through & Blind pores measurable
Sample with pore diameter 2000 µm measurable	Samples with greater than 200 µm pores difficult to measure

Mercury-free liquid intrusion technique has been developed recently and instruments are available commercially from Porous Materials Inc. USA. The Water Intrusion Porosimeter offers an alternative to mercury porosimetry for hydrophobic samples only (samples not wetted by water). The Water Intrusion Porosimeter performs a wide array of tests including total pore volume, pore volume distribution, mean pore size, and bulk density (Porous Materials 2008c). According to the manufacturer, the water intrusion porosimeter is ideal for quality control of hydrophobic materials, as tests are non-destructive and less than 10 minutes in length. Characteristics of the method are shown in Table 2-34.

According to an unpublished Swedish study from 2004, alternatives are not available for pore sizes larger than 0.2-0.3 µm (2,000-3,000 Å) (Swedish Chemicals Inspectorate 2008). For smaller pore sizes the pore structure can according to the study be analysed with a BET instrument (BET: Brunauer, Emmett and Teller, inventors of the theory behind). The BET analyser applies small amounts of a gas (the adsorbate) that sticks to the surface of the solid (adsorbent) and tends to form a thin layer that covers the entire adsorbent surface, and on this basis the sample's surface can be measured. The technique is applied in a wide variety of industries. BET instruments is e.g. provided by Quantachrome Instruments in the Nova®e series for analysis in the 0.0035 µm to >0.400 µm range. The equipment is not marketed as an alternative to mercury porosimetry, rather as a supplementary method. Whereas the mercury porosimeter is used for pore size and pore volume distribution, the BET surface area analyser is used for pore size and surface area determination, and could perhaps therefore substitute for mercury porosimetry in some applications.

Three out of four producers of mercury intrusion porosimeters state that adequate alternatives are not available today. One producer characterises the mercury method as "state of the art of macropore and ultramacropore characterization".

Table 2-34 Characteristics of mercury porosimeters, liquid extrusion porosimeters and water intrusion porosimeters (Based on Porous Materials 2008d)

	Characteristics	Mercury intrusion porosimeter	Liquid extrusion porosimeter	Water intrusion porosimeter
Pore structure characterization	Mean pore size	x	x	x
	Pore size distribution	x	x	x
	Total pore volume	x	x	x
	Liquid permeability		x	
	Porosimetry surface area	x	x	x
	Bulk density	x		x
	Absolute density	x		
	Particle size distribution	x		
Sample characteristics	Pore size range	0.0035 - 500 µm	0.05 - 2000 µm	0.001-20 µm
	Surface area range	1-100	not indicated	1-100
	Dead end and through-pores	x		x
	Special sample characteristics	indicated as N/A	not indicated	Hydrophobic
Applications	Automotive industry	x	x	x
	Battery/fuel cell industry	x		x
	Ceramic industry	x	x	x
	Chemical industry	x		x
	Filtration industry	x	x	
	Geotextiles/textiles industry		x	
	Nonwovens industry		x	
	Paper industry	x		x
	Pharmaceutical/medical industry	x	x	x
	Powder metallurgy industry	x	x	x

Alternatives to mercury pycnometers, using a gas displacement technique to measure volume, are marketed by Micromeritics and possibly other manufacturers. Inert gases such as helium or nitrogen are used as the displacement medium (Micromeritics 2008). Accupyc 1330 and 1340 instrument models can provide data that is similar to Apparent Skeletal Density data on the Hg pycnometer. Geopyc 1360 instrument model can provide data that is similar to Bulk Density data on the Hg pycnometer.

2.8.1.2 Calibration of mercury monitors

Environmental mercury monitors are used to monitor very low concentrations of mercury in ambient air. The monitors are calibrated by passing a gas with a known concentration of mercury into the monitor which is then adjusted to give the correct concentration reading (Goodman and Robertson 2006). The mercury is retained in a ceramic container which may be replaced when the mercury has been consumed. As the mercury is a consumable it is outside the scope of the RoHS Directive. Goodman and Robertson (2006) estimate the total EU-wide mercury consumption for calibration of mercury monitors at 0.2 kg. No alternatives are available.

2.8.1.3 Mercury triple point cells

Mercury triple point cells are used in laboratories for calibration of Standard Platinum Resistance Thermometers using the mercury triple point temperature at -38.8344°C as a standard temperature point. The mercury consumption for this purpose is estimated to be negligible.

2.8.1.4 Mercury-cadmium-telluride (MCT) in infrared light detectors

Mercury-cadmium-telluride (MCT, or cadmium-mercury-telluride – CMT) is a ternary alloy semiconductor that is used as the detector material in high-performance infrared detectors for the wavelength range 4-20 µm. The application is outside the current scope of the RoHS Directive. For this material to achieve infrared detection it has to be cooled at temperatures between -40°C and -200°C. MCT detectors have a wide range of military applications, which account for about 99% of the market (Goodman and Robertson 2006). The typical mercury quantity per detector is 10 mg (Gensch *et al.* 2006). Estimating the annual quantities to be 4,000 detectors Gensch *et al.* (2006) estimated the total mercury consumption in this product on the EU market at about 40 g. Goodman and Robertson (2006) estimated the total mercury consumption including military applications somewhat higher at about 5 kg. There are three major manufacturers of MCT in the EU and Gensch *et al.* (2006) estimated that a total of 200 g mercury per year is used for manufacture of MCT in the EU. The total mercury consumption in products including military applications is estimated at 5-10 kg.

Alternatives

A number of different materials for photodetection exist, but none of the alternatives are suitable for the wavelength range of the MCT detectors (Goodman and Robertson 2006).

2.8.1.5 Seam-welding machines

In many situations the transfer of electrical current from a shaft to a rotating part has taken place using mercury, e.g. in contactors for cranes and packaging machines (KemI 2004).

Seam-welding machines are used in the manufacture of ventilation ducting and cans (KemI 2004). In the machine, a wheel conducts an electric current through the material at the same time as a welding rod is fed in. These machines have traditionally used mercury in the upper wheel (about 60 g) and the lower wheel (a few mg).

A survey of mercury in seam welding machines has been undertaken in Sweden. There are about 100 seam-welding machines in Sweden. The mercury in the wheel oxidises and is replaced after 2-5 years. The quantity in the upper wheel is on average about 60 g so the total quantity in all the machines is probably about 10 kg. The turnover of mercury is of the order of 5 kg per annum (KemI 2004). Seam-welding machines have a life of at least 30 years.

Two manufacturers, in Italy and Switzerland, dominate the world market (KemI 2004), CEMSA S.p.A., Italy and Soudronic AG, Switzerland.

According to information from the two manufacturers, new seam welding machines do not contain mercury in the upper wheels (Soudronic 2008, CEMSA 2008) and mercury-free spare parts are available for all machines. The seam welding machines from Saudronic apply a totally mercury-free roller head system DISCON (Soudronic 2008), whereas some types of machines from CEMSA contain a few mg mercury in the lower roller heads.

Based on the available information it is estimated that the main mercury consumption for this application is for maintenance of machines already in use, whereas the consumption with new machines is small. Based on the Swedish data it is roughly estimated that the EU-wide consumption for this application is in the range of 0.2-0.5 tonne per year.

Alternatives
The technique is slightly different for straight and curved seams. According to KemI (2004) the Swiss manufacturer has developed a mercury-free technique for straight seams but the corresponding development for curved seams has proved difficult. The Italian manufacturer has not regarded the Swedish market as sufficiently interesting to consider investing in development.

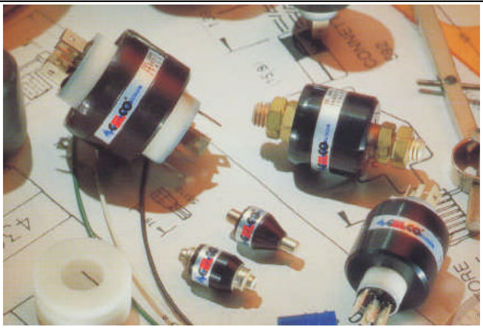
According to a Swedish survey. the machines that are used for straight seams can be modified to use a mercury-free technique. But there is currently no alternative technique for curved seams (KemI 2004).

The Norwegian general ban of mercury in products has an exemption until 2010 for seam welding machines, because the mercury-containing wheel in seam welding machines in use by two companies in Norway are replaced with a frequency of some years (SFT 2006).

2.8.1.6 Mercury slip rings

Mercury slip rings, as described for welding machines above, are used for a number of applications. A mercury slip ring is a unipolar rotary mercury ring with a hole inside. The typical application areas for a 250-1000 Ampere mercury slip ring, according to a European distributor, are welding, robotic and galvanic areas, whereas the applications for a 4-10 Ampere slip ring are wrapping machines, rotating tables, medical machines, food conveyors, testing machines, extensometers and thermocouples (Celco 2008). Mercury slip rings are typically used in machinery beyond the scope of the RoHS Directive.

Mercury slip rings are manufactured by Mercotac in the U.S.A. (http://www.mercotac.com) and distributed in the EU by among others Celco Profil. S.r.l., Italy in the Mercrotary and Mercotac product range. No data has been identified on the amount of mercury in the slip rings or the total EU consumption of mercury in slip rings. The consumption is roughly estimated at 0.1-1 tonne.



EXAMPLE:

"A great variety of industrial machinery can benefit from the use of a Mercotac Connector for power and control circuits some examples are the following:

- *Wrapping machine*
- *Rotating tables*
- *Medical machine*
- *Eating rolls*
- *Testing machines*
- *Extensometer, thermocouples*"

Manufacturer: Mercotac®, Inc., USA

Distributor: Celco Profil, Italy

Source: hhttp://www.celcoprofil.com/prodotti_mercotac_uk.htm

Alternatives

Gold plated brass slip rings and gold alloy brushes have been developed in response to the RoHS Directive and are available for most applications (Engineeringtalk 2005).

2.8.1.7 Mercury pendulums

Many old grandfather and mantelpiece clocks were fitted with mercury compensated pendulums (Medfordclock 2008). Mercury vials used for retrofitting old clocks are marketed e.g. by Medford Clock & Barometer in the USA, so mercury is evidently used in very limited amounts for repair of old clocks. The total mercury consumption for these applications is considered to be very small and < 10 kg.

2.8.1.8 Plasma display panels

According to an exemption request for the RoHS Directive, mercury is used in some plasma display panels (Babcock 2006). The mercury is hermetically sealed in the plasma display and is used to retard the cathode sputter onto the anode electrodes. The mercury content is 5-30 mg per plasma display and the manufacturer estimates the annual usage of mercury in plasma displays on the EU market is less than 150 grams (Babcock 2006).

Alternatives

The evaluation of the exemption requests recommend to grant a time-limited exemption due to the lack of suitable alternatives for the specific application (Gensch *et al.* 2007), but point at the fact that plasma displays are available on the market in mercury-free technology.

2.8.1.9 Fire gilding

Mercury has historically been use for fire gilding in which the first step in the process is to make a paste or amalgam of gold by joining fine gold and mercury (Brepohl 2001). Today electroplating is the preferred way to develop a gold coating on a metal object, but fire gilding may be applied when antique work is to be repaired or an exact replica made (Brepohl 2001). There is a clearly visible difference between the intense saturated layer of gold created in this process and the layer that results from electroplating. It is normal for 5-15% of the mercury to remain behind permanently bound up with the gold, but if more than this remains the result is a pale colour (Brepohl 2001). The process is probably not much used today; from Denmark one recent example has been identified (Flensborg Avis 2004) and from the UK one example has been identified

(Loomes 2007). The total mercury consumption for this application is most likely very small and is estimated at < 10 kg.

Jewellery consisting of or plated with gold or silver may contain some mercury. A recent Danish investigation of heavy metals in jewellery showed that 4 out of 232 pieces of jewellery contained mercury in the range of 0.6 - 2.3 % mercury (Strandesen and Poulsen 2008). Two of the pieces were gold or silver plated, respectively, while the other two were “precious metal like” silver and gold, respectively. The results indicate that mercury may be present in the metals as residues either from the gilding or from amalgamation processes. Mercury is probably also present in a small percentage of jewellery marketed in other countries, but the total mercury content of marketed products has not been estimated.

2.8.1.10 Folklore medicine

Mercury is reported in the literature to be used in some types of folklore medicine.

There is a class of Ayurvedic formulas, of Indian origin, which contain compounds of heavy elements such as mercury, arsenic and lead (Maharishi Ayurveda 2007). In the EU Ayurvedic medicines are e.g. marketed and used within the Transcendental Meditation community founded by Maharishi. The Professional Association for Ayurvedic Medical Professionals and Therapists in Europe report that mercury may either be present in Ayurvedic preparations as a contaminant at trace levels or be intentionally used in a class of Ayurvedic preparations called rasa-shastr, which is derived by processing of minerals/metals (VEAT 2008). To the knowledge of VEAT neither category is officially marketed in German speaking countries, but a limited unofficial distribution of the products in various parts of the EU cannot be ruled out. VEAT has proposed that it would be very desirable to scientifically evaluate the genuine processing and the effects of rasa-shastr products.

Mercury may be used in homeopathic pharmaceuticals in extremely diluted concentrations. Germany reported (questionnaire response) that 272 human homeopathic pharmaceuticals could be identified in the country. As the mercury is extremely diluted the total mercury amount involved is considered insignificant.

The total mercury consumption for these applications is considered to be less than 10 kg.

2.8.1.11 Elbow shock absorber wristband

An elbow shock absorber wristband, which is a support that incorporates encapsulated mercury to absorb vibrations, is marketed by a U.S manufacturer (Gamma 2008). According to the manufacturer, the wristband is worn to reduce stress and prevent tennis elbow and carpal tunnel syndrome. In the EU the wristband is e.g. supplied by Apollo Leisure, U.K. (Apollo 2008). The total amount of mercury used for the application is estimated to be negligible and has not been quantified.

2.8.1.12 Lighthouses

In many countries lighthouses, which were built or rebuilt around the turn of the 19^{th} century, are equipped with lenses that float in a mercury bath which minimises friction. The principle was developed by the French lighthouse director Bourdelle in 1892 (Skov- og Naturstyrelsen 2008).

In France, 90 lighthouses out of 158 along the French coast use mercury (Cheneau 2006). The total mercury content is not reported, but one of the largest, the lighthouse of Creac’h has a reservoir with more than 60 litres (780 kg) of mercury supporting one of the most powerful and heavy optics in the world (10 tonnes, for 4 lights each 3 meters in diameter). The mercury of the lighthouses is filtered and topped up every 5 years (Cheneau 2006).

In Denmark, 12 lighthouses are equipped with mercury and contain from 6 to 200 kg of mercury (Christensen *et al.* 2004). The 12 lighthouses contain a total of about 1,400 kg of pure mercury corresponding to an average of about 120 kg per lighthouse. The Royal Danish Administration of Navigation and Hydrography annually delivers about 40 kg of mercury for hazardous waste management and the annual mercury consumption for maintaining the lighthouses is estimated at about 50 kg corresponding to about 4 kg per lighthouse.

In Sweden, 6 lighthouses are still equipped with mercury. The total mercury content of the six lighthouses, which were all built before the 1st World War, is approximately 1600 kg corresponding to an average content of 270 kg (Swedish EPA 2008).

In the UK it is reported by the General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar that more than a few lighthouses with mercury are still in operation (DEFRA 2008). They used to be cleaned on a regular basis, but this has been discontinued.

A description of lighthouses with mercury in Germany has also been found on the internet.

The use of mercury in lighthouses in other Member States has not been investigated, but it is assumed that such lighthouses exist in most Member States with a coastline. Assuming that the average mercury content is 120-250 kg per lighthouse and 200-500 such lighthouses exist in the EU, the total amount of mercury accumulated in lighthouses in the EU would be about 24-125 tonnes. If it is assumed that on average 4-6 kg mercury is used annually for topping up or replacement of mercury by maintaining the lighthouses, the EU-wide mercury consumption for maintenance of lighthouses would be around 0.8-3 tonnes/year. The main part of the mercury is estimated to be disposed of as hazardous waste, but a part of the mercury is also released to the surroundings. The release has not been estimated due to lack of data. In Denmark it has been estimated that the releases would be <10 kg per year.

By evaporation, the mercury in the lighthouses may have been responsible for exposure of the lighthouse keepers. Lighthouse keepers on the West Coast of Canada were reported to have displayed bizarre and erratic behaviour (Walter 2002). According to the author the behaviour may be explained by chronic low dose mercury vapour toxicity from mercury used to support the large weight of the lens and lighting system.

Alternatives
Newer lighthouses do not use mercury. The only alternative to using mercury in old lighthouses, expressly designed for the use of mercury, is to change the whole optical system (Cheneau 2006).

2.8.1.13 Mercury in large bearings of rotating machinery in for example older wastewater treatment plants.

Mercury has previously been widely used in large bearings of rotating machinery in for example older wastewater treatment plants. Some use probably still takes place and small amounts of mercury are used for maintenance of bearings. The total consumption is roughly estimated at 0.05 - 0.5 tonnes.

2.8.1.14 Gold extraction.

Gold extraction has previously been widespread in French Guiana which is officially part of the EU territory. Today mercury use in gold mining is prohibited, but takes place illegally (France, questionnaire response). According to a news-paper article in 2007 up to 15,000 Brazilians are believed to be hiding in French Guiana, working in up to 1,000 clandestine gold mine sites (The Guardian 2007). France has this year intensified the combat against these illegal activities. A recent estimate of the consumption of mercury for this illegal activity has been put at 3-6 tonnes per year (Veiga 2008).

2.8.1.15 Oesophageal dilators and gastrointestinal tubes with mercury

Oesophageal dilators (also called Maloney or Hurst bougie tubes) are used to dilate the esophagus in cases when the opening has narrowed. The dilator is slipped down the patient's throat into the oesophagus, allowed to remain in place for several minutes, and extracted. Gastrointestinal tubes contain mercury (also called Miller Abbott, Blakemore or Cantor tubes) have been common in the extraction of intestinal obstructions. Bougie tubes may contain up to 1361 g mercury whereas Cantor tubes and other gastrointestinal tubes are reported to contain 54 - 136 g mercury (Sustainable Hospitals 2003a).

According to an article in the journal *Current Treatment Options in Gastroenterology,* mercury filled dilators have today been replaced by tungsten filling (Nostrant 2005). Mercury filled dilators are still manufactured by Medovations, USA who also manufacture mercury-free alternatives (Medovations 2007). According to the manufacturer the mercury-filled types are not marketed in the EU (personal communication Dec 2007).

It has not been possible to identify any manufacturers or suppliers of mercury-containing gastrointestinal tubes. A previous investigation in the USA (Gallican *et al.* 2003) did not identify any manufacturers, but reported that unweighted tubes were available and that some customers added their own mercury. Description of Cantor tubes used for intestinal decompression from the manufacturer Teleflex medical, USA, mention that hospital protocol must be followed for mercury disposal (Teleflex 2007) indicating that the tube is meant to be filled with mercury. Mercury filled tubes are most probably not used in the EU.

Alternatives

The alternatives to mercury-filled oesophageal dilators and gastrointestinal tubes use a tungsten gel to provide the flexible weight. Because tungsten is a solid at room temperature, the tungsten within the device is a powder suspended in a gel. In 2002 the price of the tungsten filled alternatives were slightly more expensive than mercury-filled Oesophageal dilators, but already at this time mercury filled dilators were not widely available (Gallican *et al.* 2003).

2.8.1.16 Recoil suppressors for rifles and shotguns

Recoil reduction systems use the inertia principle of moving a mass of weight within the gun to slow down and offset part of the apparent recoil. The mercury recoil suppressor (or recoil reducer) works on the principle that the moveable weight is liquid mercury, free to react instantly when the gun is fired (C&H Research 2007). The mercury in the suppressor is sealed in a steel tube. The mercury recoil reducer of a Benelli Nova shotgun has 14 oz (28 gram) of mercury (Gunslot 2007). Other recoil suppressors seems to be of similar size. The mercury recoil suppressers are produced in the USA by C&H Research and Benelli USA, and seems to be widely used in the USA.

Suppliers of these type of recoil suppressors in the EU have not been identified.

Alternatives

Most devices sold for recoil suppression contain two springs and a lead or steel weight (C&H Research 2007).

2.8.1.17 Vacuum pumps with mercury

A vacuum pump is a device that removes gas molecules from a sealed volume in order to leave behind a partial vacuum. Different general purpose types of mercury vacuum pumps are manufactured by Kimble/Kontes, USA, a manufacturer of laboratory equipment. One of the types is reported to require 250 ml (3.4 kg) mercury (Kimble/Kontes 2007). While these pumps are still reported to be in operation in the EU, it has not been possible to obtain any evidence of recent marketing of this equipment in the EU.

2.8.1.18 Tire balancers

Mercury-containing tire balancers are counter-balancing mechanisms composed of mercury filled tubes that are fitted to rotating mechanical parts. It is reported that tire balancers are used in Canada today mostly on tires in various types of vehicles including trucks, cars, motorhomes, motorcycles, jetskis, and ultralites (Environment Canada 2007). Environment Canada (2007) estimates that each mercury-containing balancer contains 99.2g of mercury. From 2000-2004, 744 kg of mercury were used in tire balancers in Canada. Mercury tire balancers in vehicles are prohibited in the EU by the ELV Directive. If any use occurs in the EU, e.g. in jetskis or ultralites (small flying machines) beyond the scope of the ELV Directive, the total mercury quantity is estimated to be small.

2.8.1.19 Liquid mirror telescopes

A liquid mirror telescope (LMT) is a telescope that consists of a spinning horizontal disk containing a reflective liquid, typically mercury. Up to very recently, every large liquid mirror (LMT) constructed used liquid mercury as its reflective liquid (Laval University 2008). The mercury layer can be thought of as a thin liquid highly reflective coating. The amount of mercury depends on the size of the mirror. A 1 mm layer of mercury all over the surface of a 2.5 meter mirror requires 5 litres of mercury, about 70 kg (Laval University 2008). Liquid mirror technology can be applied to other areas of science besides astronomy and is e.g. applied in laser radars (lidar) used in atmospheric research (UWO 2008). No description of the use of liquid mercury mirrors in the EU has been found, but several European research institutions are involved in the planning or in the elaboration of a telescope with a 4-meter liquid mirror, the ILMT (International Liquid Mirror Telescope) (ILMT 2003).

Alternatives

Gallium and gallium alloys has been investigated as possible replacements for mercury in liquid mirrors (Laval University 2008).

2.8.1.20 Target in spallation neutron sources

In spallation neutron sources, neutrons are produced by spallation as pulses of protons are bombarded onto a neutron producing target. The target may be liquid mercury. Just a few units exist around the globe. Each unit contain tens of tonnes of mercury e.g. the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory USA, started in 2006, contain 18 [short] tons of circulating mercury as target (Anderson and Holtkamp 2006).

For the proposed European Spallation Source (ESS), mercury have been chosen for both target stations (Hansen *et al.* 2003). Each on of the two targets is planned to consist of 1200 litres of liquid mercury (about 16 tonnes), encased in a steel container (European Neutron Portal 2007).

According to ORNL Neutron Science (2007) mercury was chosen for the target for the Oak Ridge National Laboratory SNS because (1) it is not damaged by radiation, as are solids; (2) it has a high atomic number and (3), because it is liquid at room temperature, it is better able than a solid target to dissipate the large, rapid rise in temperature and withstand the shock effects arising from the rapid high-energy pulses (ORNL 2007).

Mercury is still not used for spallation neutron sources in the EU.

2.8.1.21 Pressure holding devices in district heating plants

Mercury pressure holding devices have historically been used in district heating systems. Each of these devices contain several hundred kilograms of mercury in a U-bend tube. In Denmark more than 300 plants were until the end of the 1980s equipped with such devices and the sewer systems of many plants are still contaminated with mercury from former mercury blow-outs for the tubes. (Markmann *et al.* 2001). It has not been possible to identify any current use of these devices in district heating plants.

2.8.1.22 Applications described in the literature for which it has not been possible to find any evidence of present use of mercury

It has not been possible to obtain any evidence of uses within the EU for the following applications of mercury described in the literature:

- Certain colour photograph paper types;
- Toys, novelties or games;
- Browning and etching steel.

2.8.2 Current mercury consumption and trade

The available information on the consumption of mercury for miscellaneous applications is summarised in Table 2-35 below. Two of the major uses, porosimetry and maintenance of lighthouses, have not been quantified in previous studies of mercury use in the EU.

Table 2-35 Mercury consumption for miscellaneous applications in 2007

Application	Consumption Tonnes Hg/year
Porosimetry and pycnometry	10 - 100
Conductors in seam welding machines (mainly maintenance)	0.2 - 0.5
Mercury slip rings	0.1 - 1
Maintenance of lighthouses	0.8 - 3
Maintenance of bearings	0.05 - 0.5
Gold production (illegal)	3 - 6
Other applications	0.5 - 3
Total (round)	15 - 114

2.8.3 Mercury accumulated in society with miscellaneous uses

It is estimated that the major stock of mercury accumulated in the EU with the miscellaneous uses is in lighthouses and large mercury bearings.

If it is assumed on the basis of the description in section 2.8.1.12 that the average mercury content is 120-250 kg per lighthouse and 200-500 such lighthouses exist in the EU, the total amount of mercury accumulated in lighthouses in the EU would be about 24 - 125 tonnes.

If it is assumed that the 1000-2000 porosimeters at any time in average are filled with 2 kg mercury it represent a stock of 2-4 tonnes mercury.

Metallic mercury for educational uses accumulated on shelves of schools and universities may be significant. These stocks are not considered as accumulated in products and are treated separately in section 3.1.4.1.

Apart from current applications of mercury in the EU described in the previous subsections, mercury may be accumulated in some of the mentioned products with no demonstrated current use, but with products still circulating in society. This could e.g. be in oesophageal dilators and gastrointestinal tubes, large mercury bearings.

In summary, the total amount accumulated in the EU in miscellaneous products apart from lighthouses is roughly estimated at 50 tonnes.

2.8.4 Mercury-free alternatives

Table 2-36 summarise information on marketed alternatives for mercury products known to be marketed within the EU today. For other applications, for which no evidence of mercury products marketed today has been obtained, it is deemed that suitable alternatives are readily available on the EU market.

The indicated substitution level is based on information on substitution level provided by Member States (see Annex 1) supplemented by an assessment made by the authors. A range indicates that different substitution levels are reached in different Member States.

For mercury used for maintaining the bearings of rotating parts in lighthouses and wastewater treatment plants, the alternative would typically be to replace the rotating part with new parts e.g. new lens system in lighthouses.

Table 2-36 Overview of marketed alternatives to mercury-containing miscellaneous products marketed in the EU

Application area / product type	Marketed alternatives	Price of alternatives compared to mercury usage	Substitution level	Remarks
Mercury porosimetry	For some poresizes no alternatives seem to be available	- /no alternatives	2	For materials which can be measured by alternative methods, the alternatives are less costly
Mercury pycnometers	Gas displacement techniques	N	N	
Mercury-cadmium-telluride (MCT) in infrared light detectors	For certain wavelength ranges alternatives are not available	no alternatives	0	
Calibration of mercury monitors	no alternatives	no alternatives	0	
Plasma display panels	Most plasma display panels apply mercury-free technology	=	4	
Fire gilding	Electroplating	-	4 general 0-2 specific restoration work	Electroplating may not give exactly the same appearance - relevant by restoration work
Conductors in seam welding machines	Mercury-free conductors	N	3-4 (new equipment)	Mercury-free conductors may not be available for replacement in existing machines Differences between machines for straight and curved welding
Mercury slip rings	Gold plated brass slip rings and gold alloy brushes	N	N	
Pigments for art and restoration work	A number of organic and inorganic pigments	N	4 general 0 specific restoration work	Mercury compounds in general phased out for art work For restoration of some specific colours substitutes may not be available

Key assigned to the overall current user/consumer price levels for mercury-free alternatives as compared to mercury technology:
- – Lower price level (the alternative is cheaper)
- = About the same price level
- + Higher price level
- ++ Significant higher price levels (more than 5 times higher)
- N Not enough data to assign an indicator

Key to assigned substitution level indices:
- 0 No substitution indicated in assessed data sources; development often underway
- 1 Alternatives are in commercial maturation, or are present on the market but with marginal market shares
- 2 Alternatives are commercially matured and have significant market shares, but do not dominate the market
- 3 Alternatives dominate the market, but new products with mercury also have significant market shares
- 4 Mercury use is fully, or almost fully, substituted
- N Not enough data found to assign an indicator
- ? Indicator very uncertain due to limited data

2.8.5 Producers of mercury-containing products

The following list of manufactures of mercury-containing miscellaneous products in the EU is based on Member State responses to the questionnaire, internet search and contact to market players. The list is not considered comprehensive, and other producers for both these product groups and other product groups may exist.

Country	Product type	Name of producer
IT	Instrument for mercury intrusion porosimetry (mercury added by he user of the instrument)	Thermo Fisher Scientific, Milan (formerly Carlo Elba; or CE Instruments)
IT	Seam welding machines	CEMSA S.p.A., Italy

2.8.6 Collection and treatment of waste

As this product group consists of many different applications and virtually no information on the collection and treatment of the waste is available the distribution of the mercury flow among the different waste streams can only be done with high uncertainty.

Mercury used in illegal gold production is estimated to be released during use.

Of the other applications, mercury for porosimetry accounts for the mercury in waste. From Denmark it is known that a major part is sent to recovery, while a minor part goes with the hazardous waste stream, but it seems to be relatively recent that the waste is sent to recovery. Mercury recyclers seem not to receive a large amount of mercury from this source, so it is roughly estimated that 20% of the 10-200 tonnes is recycled while the rest is disposed of in hazardous waste landfills.

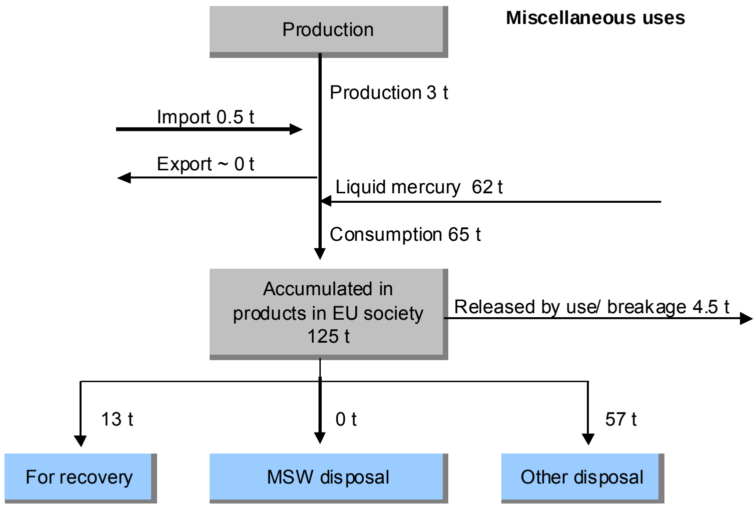
Mercury for other applications is roughly estimated to be 50% recycled, 50% disposed of as hazardous waste. Mercury going into municipal solid waste is assumed to be insignificant for these miscellaneous applications.

2.8.7 Data gaps

As the large quantities of mercury for porosimetry have not been described before, hardly any information on the treatment of the waste is available.

2.8.8 Mercury mass balance

The data obtained on the flows of mercury in miscellaneous applications are summarised in the flowchart below.



2.9 Summary

Mercury consumption in products and industrial processes in the EU 2003 and 2007 is shown in Table 2-37, and demonstrates the value of closer scrutiny of specific applications of mercury. A more detailed summary table for 2007 has been provided in the summary of the report in Table 0-1.

Consumption is defined here, depending on the application area, as:

- the quantity of liquid mercury applied during the specified year for industrial processes (e.g. chlor-alkali) or laboratory analyses;
- the quantity of liquid mercury used for maintenance of equipment (e.g. lighthouses); or
- the mercury content of products marketed in the EU during the specified year (e.g. batteries).

It should be noted that the present estimates apply to EU27+2 whereas the two previous estimates applied to EU15+2 and EU25. Only for two product groups, measuring equipment and switches, relays, etc., has a significant decrease been observed between 2001 and 2007.

For light sources the 2007 consumption is higher than the 2001 estimate (even when considering the differences in geographical coverage). The increase over 2001 is mainly due to a marked increase in the use of mercury-containing lamps for backlighting of flat panel displays in electronics.

The mercury consumption in batteries has been derived from information on mercury in the waste stream. However there may be other high imports of mercury batteries for exempted applications that do not go to the public waste stream, so it is not possible to compare with the previous estimates.

The apparent increase in the use of mercury with chemicals and miscellaneous uses from 2003 to 2007, especially when the high estimate is considered, does not reflect a major increase in consumption, but may be due to an underestimate in 2000 of the mercury use with PU catalysts and for porosimetry (porosimeters were included in measuring equipment, but not believed to be a significant use).

The mercury use with dental amalgams and for chlor-alkali is of the same general magnitude when the larger population of EU27+2 is considered.

Table 2-37 Evolution of mercury consumption in products and industrial processes in the EU 2001, 2005 and 2007

Application area	Mercury consumption, t/year			Percentage
	2001 *1	2005 *2	2007	of total, 2007
Chlor-alkali production	n.a.	190	160 - 190	41
Light sources	5.9	35	11 - 15	3
Batteries	9	20	7 - 25	4
Dental amalgams	90	90	90 - 110	24
Measuring equipment	33	35	7 - 17	3
Switches, relays, etc.	9	35	0.3 - 0.8	0.1
Chemicals			28 - 60	10
Miscellaneous uses	55 *3	35 *3	15 - 114	15
Total (round)	202 + n.a.	440	320 - 530	100

*1 EU 15 + Czech Republic, Poland and Slovenia. Source Floyd et al. 2002. "Miscellaneous uses" actually indicated as "Other products".

*2 EU 25 Source: Maxson (2006).

*3 "Miscellaneous uses" includes consumption with chemicals.

The information on mercury accumulated in the EU in products and industrial facilities is summarised in Table 2-38. These stocks are also compared with the other mercury stocks in society in a summary table in the executive summary in Table 0-2.

Chlor alkali production facilities represent by far the main stock, followed by dental amalgams and chemicals.

Table 2-38 Mercury accumulated in society in the EU in products and industrial processes

Products or installation	Accumulated Tonnes Hg	Percentage of total
Chlor-alkali production	13,100	88
Light sources	65	0.4
Batteries	99	0.7
Dental amalgams	1,000	7
Measuring equipment	70	0.5
Switches, relays, etc.	125	0.8
Light houses	75	0.5
Chemicals	300	2
Other miscellaneous applications	50	0.3
Total accumulated (rounded)	14,900	100

The information on mercury waste handling is summarised in section 4.4.

With regard to the overall mercury flow in the EU, below, please note that the sum of outputs is higher than the sum of inputs, reflecting the trend of decreasing use of mercury for some applications. Mercury releases from the products have not been a main focus of this study, and the releases are calculated only for establishing an overview of the total flows of mercury. The total emissions to the air from products in the EU have recently been estimated at 10-18 tonnes for technical products and at 2-5 tonnes from cremation (the latter is included here in “other disposal”) (Kindbom and Munthe 2007).

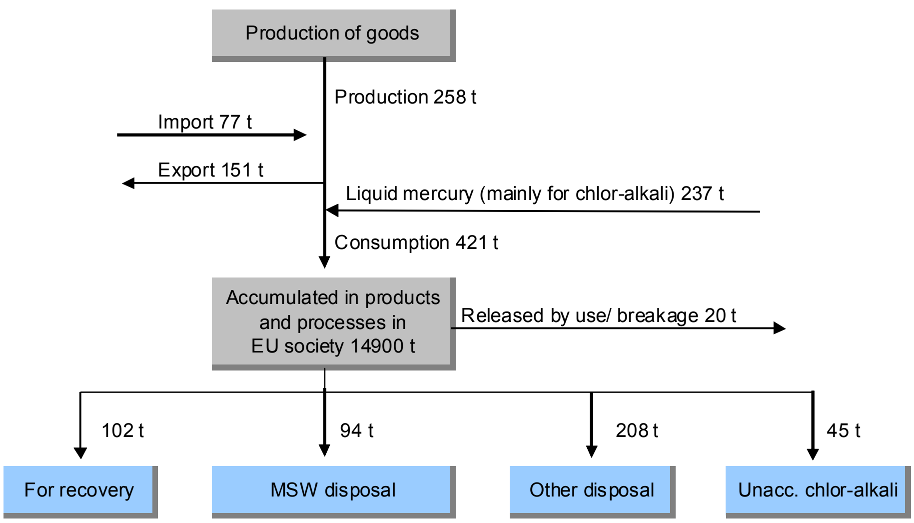


Figure 2-9 Mercury balance for EU 27+2 in 2007, best estimate

In total more than 50 manufacturers of mercury-containing products in the EU have been identified. The list is not considered complete, but is assumed to include the major manufacturers within most product categories. The companies range from small family owned workshops to major companies in the EE sector, with the majority of the companies in the small- and medium-sized enterprise range.

Besides the companies manufacturing mercury-containing components, a large number of companies may apply the components for manufacturing composite components or final products. Mercury wetted reed switches are used, e.g., by at least six manufacturers in the EU for production of mercury reed relays and switching components, and these components are further used by a large number of manufacturers of electronic equipment. Likewise a large number of companies are potentially involved in production of polyurethane elastomers or paints that contain mercury compounds used as catalysts or biocides, respectively.

Table 2-39 Identified producers of mercury-containing products in the EU27, Norway and Switzerland

Country	Product type	Name of producer
Light sources		
NL	Light sources	Philips - Philips Lighting, The Netherland
DE	Light sources	Aura - Aura Lighting Group, Germany
DE	Light sources	BLV, Ushio Group, Japan
HU	Light sources	GE - GE Consumer & Industrial Lighting, Hungary
BE, DE, UK	Light sources	SLI Sylvania, Germany
DE	Light sources	Narva - NARVA Lichtquellen GmbH + Co. KG, Germany
DE, CZ	Light sources	Osram GmbH, Germany
Batteries		
UK	Batteries	Duracell Batteries Ltd.
UK	Batteries	Energizer SA
Dental amalgams		
CH	Dental amalgams	Coltène Whaledent
CZ	Dental amalgams	SAFINA, a.s.
DE	Dental amalgams	DMG Chemisch Pharmazeutische Fabrik GmbH
DE	Dental amalgams	Dr. Ihde Dental GmbH
DE	Dental amalgams	M & W Dental
DE	Dental amalgams	Merz Dental GmbH
ES	Dental amalgams	Madespa S.A
FR	Dental amalgams	Dentoria SAS
FR	Dental amalgams	Specialities Septodont
NL	Dental amalgams	Cavex Holland BV
SW	Dental amalgams	Ardent AB (Ivoclar Vivadent)
Measuring equipment		
UK	Gyrocompasses	Kelvin Hughes Limited, UK.

Coun-try	Product type	Name of producer
IT	Manometers (The manometers are added mercury by the user)	Guissani srl., Italy
FR	Mercury-containing reference electrodes, mercury hanging drop electrodes	Radiometer Analytical SAS, France
CH	Mercury drop electrodes for voltammetry and polarography (The electrodes are added mercury by the user)	Metrohm Ion Analysis, Switzerland
UK	Mercury sphygmomanometers	AC Cossor & Son (Surgical) Ltd., UK
DE	Mercury sphygmomanometers	Rudolf Riester GmbH & Co. KG, Germany
DE	Mercury sphygmomanometers	ERKA. Kallmeyer Medizintechnik GmbH & Co. KG
FR	Mercury sphygmomanometers	Spengler , France
FR	Tensiometers	SDEC France, France (production will be dis-continued in 2008)
DE	Thermometers	Sika Dr Siebert und Kühn & Co. K, Germany
DE	Thermometers	Ludwig Schneider GmbH & Co. KG, Germany
DE	Thermometers	Klaus-Dieter Radschuwait, Germany
FR	Thermometers, hydrometers	ALLA FRANCE, France
FR	Thermometers, barometers, hygrometers	STIL, France
IT	Thermometers, barometers, hygrometers	Gusmini & Balconi S.R.L., Italy
UK	Thermometers	S Brannan & Sons Ltd, UK
RO	Thermometers	SC Termodensirom, Romania
UK	Thermometers, barometers, hygrometers	Russell Scientific Instruments Ltd., UK
DE	Thermometers, hydrometers, hygrometers	AMARELL GmbH & Co. KG, UK
CZ	Thermometers	Exatherm, Czech Republic
BE	Barometers	Dingens Barometers, Belgium
NL	Barometers	H.N. Rose Barometers Schiedam, the Nether-lands
Switches, relays		
UK	Mercury vibration sensors	Cooper Menvier Ltd., UK
BE	Mercury wetted reed switches and relays, vibration sensors, tilt switches, float switches	Comus International Bvba, Belgium (manufactur-ing of the tilt switches outside EU)
DE	Mercury float switches	HERMETIKO Bauteile GmbH
IT	Mercury float switches	MATIC s.r.l., Italy - mercury switches manufac-tured for export to non EU countries only
UK	Mercury tilt switches	Russell Scientific Instruments Ltd., UK
Mercury chemicals		
DE	Mercury chemicals	Chemos GmbH, Germany
DE	Mercury chemicals	Fox Chemicals, Germany
DE	Mercury chemicals	Scharlab SL, Germany
ES	Mercury chemicals	Gomensoro SA, Spain

Coun-try	Product type	Name of producer
ES	Mercury chemicals	Panreac Quimica SAU, Spain
UK	Mercury chemicals	Johnson-Matthey Ltd, UK
ES	Mercury catalyst for PU	Thor Especialidades, S.A.
Miscellaneous applications		
IT	Instrument for mercury intrusion porosimetry (the porosimeters are added mercury by the user)	Thermo Fisher Scientific, Milan (formerly Carlo Elba; or CE Instruments)
IT	Seam welding machines	CEMSA S.p.A., Italy

3 Mercury sources, stocks and contaminated sites

The quantities of mercury accumulated in society in product applications have been discussed in previous chapters. The focus of this chapter is on other mercury stocks in the EU that may be drawn upon to meet future demand, as well as ongoing sources of mercury such as by-product mercury from non-ferrous mining operations. The discussion of contaminated sites is relevant here only to the extent that they may also be “stocks” of mercury that could be recovered to meet eventual demand.

Stocks of mercury may be readily available (such as mercury on the shelf, or in storage tanks at Almadén), easily recoverable (such as a pool of mercury under a closed chlor-alkali facility cell-room), or not so easily recoverable (such as extensive soil contamination) depending on the mercury recovery cost that is considered acceptable. In all of these cases the amount of mercury in the stock is finite, and whatever fraction of the mercury is considered to be cost-effective may be recovered rather quickly.

On the contrary, a mercury “source” (such as trace mercury removed from zinc ores, or collected during the purification of natural gas) would typically generate a certain amount of mercury every year over a period of many years.

3.1 Specific metal mercury stocks

3.1.1 Mercury cell chlor-alkali plants

In 2005 there remained about 6 million metric tonnes of mercury cell chlorine capacity operating in the EU27 (Euro Chlor 2005). During 2005-2007, the discontinuation of one-half to one million metric tonnes of European Union mercury cell chlorine capacity were announced by industry, including plants in Italy, Poland, etc. The chlor-alkali plants operating with the mercury cell process in the EU are listed in Annex I.

In chapter 2.1 it has been calculated that these plants are holding a stock of some 13,100 tonnes of readily recoverable mercury, mostly in the electrolytic cells, that will be liberated as the plants are decommissioned between now and 2020 and beyond.

3.1.2 Mercury storage at Almadén

The mine site at Almadén has a stock of cinnabar ore above-ground, though covered with a layer of soil, amounting to some 50-60 thousand tonnes, and containing an estimated 1,500-2,000 tonnes of mercury. As a source of “primary” mercury that the EU has decided should not be added to the biosphere, there are no plans to exploit this ore, and as it is not in liquid form, it is not included in the inventory here.

On the other hand, there are large mercury storage tanks at Almadén that hold mercury previously refined at the site as well as mercury sent to Almadén from decommissioned chlor-alkali facilities. While Almadén management has declined on more than one occasion to reveal how much mercury is in storage, estimates by others in the industry are on the order of 3,000 tonnes or more in 2007. This quantity fluctuates as mercury is bought and sold, but would generally be expected to decline overall until mercury can no longer be exported from the EU.

The famous mercury fountain
Although not included in the above calculation since the mercury is not considered to be available, one of the more unique mercury stocks in the EU is the hundreds of kilos in the mercury fountain created by Alexander Calder, on display at the Fundació Joan Miró in Barcelona.

This fountain was created by Calder as a tribute to the mercury miners of Almadén

Source: http://www.ics.uci.edu/~eppstein/pix/bar/miro/Almaden1.html

3.1.3 Mercury held by metals dealers and recyclers

It is impossible to know how much mercury is in the inventory of other metals traders, dealers and recyclers. If one assumes stocks of 6-12 months' sales, not including typical sales of Almadén (included above), this stock would amount to another 150-250 tonnes of mercury, including mercury held in entrepôt warehouses that would otherwise be in the EU territory.

3.1.4 Mercury in laboratories, schools and clinics

3.1.4.1 Laboratory and clinic shelves and piping

As part of the Swedish Action Programme for collection of mercury in the late 1990s, in total 10-11 tonnes of mercury was identified by all projects under the Action Programme.

As part of the program the Swedish EPA undertook a number of surveys of mercury stored on shelves or accumulated in water traps in laboratories of institutes and schools, as well as priority industries. The results are summarised in Table 2-31. Of the 3 tonnes found in laboratories of schools and institutes, 600 kg was identified and cleaned from the laboratory water traps, while 300 kg was kept in instruments (Swedish EPA 1999). It was estimated that around 85% had been cleared out of universities and colleges and 80-90% cleared out of schools.

Table 3-1 Results of Swedish EPA's surveys with mercury sniffer dogs (Swedish EPA 1999)

Sector	Year	Investigated installations	Collected mercury, tonnes
Main users of mercury in laboratories in Sweden	1997	7,300 water traps in 2,300 locations in 170 institutes	1.7 t, mostly from store-rooms and shelves
School laboratories	1998	20,000 water traps in 6000 premises in 1076 schools	1.3 t, mainly in laboratory instruments or glass bottles
Prioritised industries	1999	74 industrial companies	1.2 t

If the 600 kg found in sinks represent around 85% of the total in schools, colleges and universities, then 100% would be around 700 kg. As mercury in general has been phased out earlier in Sweden than in most EU countries it may be assumed that the situation in Sweden in the late 1990s may resemble the EU average today. If the Swedish experience with mercury in water traps is extrapolated to an EU-wide estimate assuming a similar amount per capita in the other MS, the total amount trapped in laboratories in the EU would be around 35-45 tonnes, which will be used as a best estimate.

Based on similar assumptions the total amount of mercury on shelves in the EU (subtracted the amount in instruments included in section 2.5) may be estimated at around 160-200 tonnes.

Finally, assuming that the majority of mercury in drains might be found in dental clinics, it is useful to note that in a study of dental clinics in Sweden, "…the total amount of pure Hg collected from tanks and pipes was 5,899 g from 11 clinics of which 3,891 g Hg originated from Clinic B," and not all pipes and drains were accessible for cleaning (Hylander et al. 2006). European dental associations estimate one dentist per 1,200-2,000 population in different countries of the EU, implying some 315,000 dentists, or 150,000 clinics or dental offices, of which most have dealt with mercury in recent years, or at least since the piping was replaced. If one assumes that some 500 g of mercury might be trapped in the piping of the average clinic, even a conservative estimate would put the total at some 50-70 tonnes of mercury for the EU27+2. Combined with the estimated mercury accumulated in water traps in laboratories of institutes and schools, this would suggest a total EU stock of 85-115 tonnes of mercury.

3.1.5 Mercury in Swedish wastes held for eventual disposal

There is no recycling of mercury in Sweden except for within the chlor-alkali industry. Mercury-containing waste such as thermometers, light sources, measuring equipment and electrical components are, however, reprocessed to separate the mercury fraction from the rest of the waste. The mercury fraction is then put in intermediate storage pending final storage, or stabilized and landfilled if the concentration of mercury is low enough.

Boliden Mineral AB currently stores wastes containing 350-400 tonnes of mercury. SAKAB's store of mercury waste is currently over 2,000 tonnes, which SAKAB estimates to contain 80-90 tonnes of mercury.

These quantities will not be considered here, however, because a) they are not in the form of metallic mercury, and b) it would be contrary to Swedish law to exploit them.

3.2 Sources and mass flows of by-product mercury

Mercury is found in trace quantities in most non-ferrous ores (especially zinc, copper and lead ores in the EU), the quantities depending on a variety of geological characteristics. This is especially the case when these metals are extracted from sulphide ores, where mercury is often found as a trace element due to its affinity for sulphur (Hylander and Meili 2005). Mercury is also found in ferrous ores – once again, especially sulphide ores – and even if these ores are not the majority of those used in steel refining, they may still represent a considerable amount of mercury released during the refining process.

3.2.1 Zinc smelting

Recovering mercury during the zinc refining process may be done to comply with regulatory requirements, or it may be done if the value of the mercury recovered is greater than the cost of alternative disposal of mercury waste. For many years the largest producer of by-product mercury in the EU27 has been Finland, where Boliden (formerly Outokumpu Oyj) has refined zinc and copper ores, including zinc concentrates imported from Sweden.

Mercury occurs in all Boliden smelter wastes, and is believed to occur in the wastes at all smelters processing sulphide ores, although other smelters in the EU have not reported it. Kokkola is the major site that sells recovered mercury, amounting to between 20 and 75 tonnes of mercury in referent years. As of 2004 or 2005, the mercury has been sold by Boliden to Lambert Metals (or affiliate) and stored in Rotterdam until resale, under the condition that it is resold to customers pre-approved by Boliden. The mercury from Boliden is sold to five pre-approved customers within the EU (Boliden 2006). Recent Boliden mercury sales are summarised in the following table.

Table 3-2 Annual mercury sales by Boliden, Finland 2001-2005

Finland	2001	2002	2003	2004	2005
Zinc smelter production (metric tonnes zinc)	222,880	247,180	235,300	265,900	235,000
Mercury exported to Netherlands (metric tonnes mercury)	82.8	77.6	54.9	25.5	23.5
Mercury export/zinc production	0.000372	0.000314	0.000233	0.000096	0.000100

Sources: ILZSG (2006) "Lead and Zinc Statistics," Boliden (2006), UNDESA/SD Comtrade (2006) export statistics.

It may be seen in this table that mercury sales by Boliden have declined greatly in recent years while the quantities of zinc smelted in Finland have remained relatively stable. This is explained largely by the fact that one of the key suppliers of zinc concentrate to Finland was a Spanish mine that phased out its operations in recent years. The Spanish concentrate had an especially high mercury content. Thus it is evident that the potential magnitude of this mercury "source" depends entirely on the origin and quantity of the ores smelted.

With regard to other Boliden operations, the amount of mercury in wastes from the copper smelter at Rönnskär (Sweden) is approximately 20 tonnes mercury per year. Waste from the zinc smelter at Odda (Norway) contains 20 tonnes mercury and the copper smelter at Harjavalta (Finland) produces annually waste containing 5 tonnes mercury. The mercury from Harjavalta and Odda presently goes to final disposal in a bedrock repository, and in the case of Rönnskär, the Swedish government has decided that the mercury should be disposed of in the same manner, although a suitable location has not yet been identified. In the meantime the waste is held in an “intermediate disposal” facility.[3]

The table below shows how much zinc is refined in the EU annually. Lawrence (Mercury 2002) noted that the main by-product mercury producers in the EU include Finland, Italy, Germany and Spain. Belgium could possibly be added to this list, receiving large quantities of zinc concentrates from Sweden.

Even assuming a lower average mercury content in other ores than the 100 ppm in those treated by Boliden,[4] and including Bulgarian mining operations, one could estimate an additional 150-200 tonnes of mercury potentially available annually in addition to that recovered in Finland. Therefore at least 174-224 tonnes per year of mercury in zinc ores may be potentially available for the EU27 as a whole.

Table 3-3 Zinc smelter production in the EU27 (thousand metric tonnes zinc) – mostly primary zinc

EU-25	2000	2001	2002	2003	2004
Belgium	252	259	260	244	263
Finland	223	247	235	266	235
France	350	347	350	253	260
Germany	328	358	379	388	364
Italy	170	178	176	123	130
Netherlands	217	205	203	223	225
Poland	173	175	159	153	153
Spain	386	418	488	519	525
UK	76	90	98	0	0
Total	2,175	2,277	2,348	2,169	2,155

Sources: ILZSG (2006) “Lead and Zinc Statistics”

3.2.2 Copper and lead smelting

Annual EU production of copper cathode is on the order of 959 thousand tonnes from primary (mine) sources and 896 thousand tonnes from secondary (scrap) sources (BREF Non-Ferrous Metals Industries, December 2001).

EU lead production is also high, ranking first among the market economy countries with 1398 thousand tonnes in 1994, of which 52% was from secondary feed materials. The industry is responding to ecological concern by recovering ever increasing amounts of lead from scrap so that primary production is steadily declining (BREF Non-Ferrous Metals 2001).

With the help of the UNEP Chemicals Toolkit (UNEP 2005) data on mercury content of non-ferrous ores, one can make a similar calculation to that for zinc ores and estimate about 50-80 tonnes of mercury content in the lead concentrates refined in the EU27, at least 30-50 tonnes of mercury in copper concentrates, and lesser amounts in other ores. Therefore the total mercury

[3] Information from the Boliden website.

[4] See UNEP (2005) for a detailed summary of the mercury content of various non-ferrous ores.

content of all non-ferrous ores refined in the EU27 could be on the order of 300-370 tonnes annually.

This is generally consistent with a previous assessment that found, apart from mercury mines, mercury production from the processing of non-ferrous metals in Europe in 1997 was estimated at 350 tonnes. Taking all ores together, the refining processes generally produce mercury or calomel in the range 0.02 to 0.8 kg of mercury per tonne of metal produced, depending on the mercury content of the concentrate (BREF Non-Ferrous Metals 2001).

In the past, the mercury recovered from calomel in Finland comprised the majority of by-product mercury that appeared on the EU market, but in recent years more calomel and other smelting wastes are increasingly being processed as mercury prices and waste disposal costs increase. The cost of mercury recovery from calomel was described as a financial "break-even" at mercury prices in the range of present prices (personal communication Boliden). While much more of the total mercury in non-ferrous concentrates could be recovered as mercury prices increase, it is estimated, consistent with Maxson (2006), that 40-60 tonnes of this mercury is already being recovered.

3.2.3 Natural gas purification

Another source of by-product mercury, although not usually considered as related to mining, is natural gas. Most natural gas contains some mercury in trace quantities. In many regions of the world, depending on geology, such as the Netherlands, North Sea, Croatia, etc., the mercury concentrations are high enough to cause serious equipment problems during processing.

Specifically, mercury condenses as liquid mercury on the inside of piping and equipment, or it amalgamates with aluminium (most problematic) and other metals (except iron), gradually corroding and weakening the metals, which has resulted in serious industrial accidents. Pirrone et al. (2001) reported that a reduction of mercury to below 10 $\mu g/Nm^3$ has to be obtained before the gas can be used, although mercury is often removed from gas even at far lower concentrations. EU27+2 producers of natural gas are shown in the following table.

Table 3-4 Natural gas production in the EU and Norway

PJ = TJ*1000	2002	2003	2004	Hg recovery
Netherlands	2,525	2,430	2,856	yes
Italy	555	524	494	yes
Czech Republic	1.8	1.6	3	yes
UK	4,031	4,029	3,758	yes
Norway	2,755	3,083	3,277	yes but Hg not recovered
Denmark	322	307	356	minimal
Germany	740	765	710	minimal

Sources: Eurogas at http://www.eurogas.org/; IAEA statistics at http://www.iea.org/textbase/stats/

The Czech Republic has reported 0.2 tonne of Hg recovered from natural gas purification in 2004, and Croatia reportedly recovers less than 2 tonnes of mercury per year from gas drawn from the Pannonian basin near Molve (Czech Republic and Croatia stakeholder consultation responses). The Netherlands recovers much more, for example due to the relatively important mercury content in gas from Groningen (180 μg/Nm^3), as does the UK. The mercury content of gas depends entirely on the field exploited.

Using the Netherlands' estimate (Netherlands stakeholder comments, 2005) that sludge from natural gas cleaning contains about 2% mercury, the 700 t of sludge reported in 2002 contained 14 t mercury, and the 900 t of sludge reported in 2003 contained 18 t mercury. Furthermore, the filtercake (17 t in 2002 and 14 t in 2003) from natural gas cleaning was assumed by the Netherlands to contain 40% mercury, equivalent to 7 t mercury in 2002 and 6 t mercury in 2003.[5] This results in 24 t mercury recovered by the Netherlands in 2002 and 20 t in 2003, although some of that is from imported wastes from the UK and elsewhere since the Netherlands (Claushuis) receives most of the mercury-containing gas purification waste for treatment, and Batrec (Switzerland) receives much of the remainder.

Based on quantities of waste and recovered mercury provided for these sources, as well as direct discussions with EU suppliers and recyclers of gas-purification catalysts, there is good support for mercury recoverable from EU27 natural gas in the range of 40-50 tonnes, of which 25-30 tonnes are already being recovered.

3.2.4 Combined by-product mercury potential

Combining the quantities of mercury in non-ferrous ores with mercury in natural gas gives a total of 350-410 tonnes of mercury per year potentially recoverable as by-product from these sources, of which 65-90 tonnes are already being recovered.

3.3 Mercury in contaminated sites, including potentially recoverable mercury

While the European Commission is discussing how best to encourage the Member States to develop comparable inventories of contaminated sites, for now one is obliged to rely on specific contributions from Member States in order to have access to such information.

In any case, it is not the intention of this chapter to do a comprehensive EU inventory of mercury-contaminated sites. Rather, it is to be seen what general conclusions may be drawn on the basis of the limited information available on a relatively small number of known sites. Nor is it intended to determine whether it is economically viable to recover the mercury from these various contaminated sites, since such a determination would depend on a great number of factors such as the market price of mercury, the cost of obtaining mercury from other sources, etc.

The major mercury contaminated sites in the EU, which may be either decommissioned or still operating facilities, include primarily:

- Sites of chlor-alkali production using mercury cells;
- Sites of production of VCM using mercury catalysts;
- Sites of production of mercury-containing products;
- Dump sites of mercury waste from the chemical industry;
- Sites of mining and smelting of mercury - especially Mt. Amiata, Idrija and Almadén;
- Sites of mining and smelting of other ores with high mercury content.

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[5] See Netherlands (2005). These numbers are more specific and considered to be more accurate than those suggested in BREF Oil & Gas (2003), p.137.

Six Member States and Norway have reported on mercury contaminated sites for the questionnaire as shown in Table 3-5, but clearly mercury contaminated sites are present in most of the Member States.

3.3.1 Decommissioned and operating chlor-alkali facilities

The largest amounts of mercury that have been quantified, other than mining sites, are at mercury cell chlor-alkali production facilities. A table is included in Annex 4 summarising existing EU27+2 mercury-cell chlor-alkali plants, as well as those that have been closed or converted. Of the estimated 100 original sites in the EU27+2, more than 50 have been closed or converted, but most of these sites still have varying degrees of mercury contamination. Operating chlor-alkali plants in the EU27+2 have previously been shown in Figure 2-1.

As seen in Table 3-5, Norway and Sweden have reported mercury contamination at their sites in the range of 8-29 tonnes per site covering areas of 10,000-90,000 m^2 whereas a site at Kazincbarcika in Hungary is estimated to contain 360 tonnes of mercury. In fact, all sites of mercury-cell chlor-alkali production have been contaminated due to previous waste management practices, although some have been remediated and the majority of the mercury removed. In order to give some brief idea of the extent of contamination at many sites, some examples from three countries are mentioned below.

Industry has substantial experience in decommissioning mercury cell facilities, including closing, dismantling, and converting plants, not to mention remediating soil, disposing of waste, etc., at dozens of facilities in Western Europe since the mid-1980s. These facilities were closed for many different reasons, including age of the plant and equipment, lack of proximity to downstream chlorine-based chemical processes, regulatory pressures, safety concerns, excessive production costs relative to competitors (which could be due, e.g., to small size or electricity costs), etc.

When plants are decommissioned and dismantled, many types of materials – both organic and inorganic – may be contaminated by Hg. Such contamination will vary from several parts per million (ppm) to, in some cases, percentages of Hg.

Table 3-5 Mercury in contaminated sites as reported by the countries' questionnaire responses

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, etc.)
FR	Vieux Thann			100 t	Pure mercury from chlor-alkali production
FR	Saint Auban			100 t	Pure mercury from chlor-alkali production
HU	Kazincbarcika			360	Pure mercury from chlor-alkali production
	Balatonfuzfo			Soil contaminated to 2-3 m depth (2600 mg Hg/kg soil)	Pure mercury from chlor-alkali production
NO	Porsgrunn	40,000	Unknown	About 29	Pure mercury from chlor-alkali production
	Sarpsborg	90,000	Unknown	About 17	Pure mercury from chlor-alkali production

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, etc.)
SE	Bengtsfors	10,000		15	Pure Hg from chlor-alkali production
	Skoghall	60,000		8	Pure Hg from chlor-alkali production

3.3.1.1 France

According to the definition of severe contamination having a major impact on the environment, two sites were mentioned by France in its response to the questionnaire – PPC Vieux-Thann and Arkema Saint-Auban.

At the Vieux Thann site the pollution is relatively stationary. It is monitored under the supervision of local administration. This site is a former chlor-alkali facility. The pollution has little impact outside the site of the former facility. Since 2005 a comprehensive study on remediation has been ordered by the local authorities for this site, and since May 2007 the hydraulic barrier has been reinforced and source treatment carried out. In between, local authorities have forbidden the use of well water for drinking or watering crops.

The Saint-Auban site is also a former chlor-alkali facility. When it was operational, it could have been the source of the pollution of the Durance, where fishing is banned. Now that the site has been closed, there is an opportunity to make a study of the mercury contamination and the measures needed to remediate the site.

All other former and operating chlor-alkali facilities in France are potentially contaminated with mercury. Impact assessments focused on the health and environmental impacts were carried out around each production site between 2000 and 2001, and have been updated on a regular basis since then.

3.3.1.2 Hungary

Historically, there have been three mercury electrolysis units operated at the Enterprise BC site: two old units that were shut down more than twenty years ago, and one unit that still operates to date. According to the questionnaire response from Hungary, "As in all cases of chlor-alkali electrolysis units worldwide, mercury migrates from the electrolysis cells into the soil. In case of the two plants out of operation, this migration ceased after their shut down, while in case of the existing plant some technical measures were taken to isolate the ground underneath the plant." The total amount of mercury in the soil is estimated at 360 metric tonnes. More than 95% of this amount has been found under the remaining operating plant.

3.3.1.3 Czech Republic

Spolana – Buildings, soil, groundwater and surface water at the chemical plant Spolana are contaminated with mercury, while the quantity of mercury in soil and construction materials is estimated at 264 tonnes total. The groundwater contains about 154 kg of mercury in soluble form (Hg^{++}). Most contaminated objects have not been used for a long time and they are falling apart because of no maintenance since 1975, when the new production unit was opened.

Ústí nad Labem – The company has operated for a very long time, and the mercury cell facility was introduced already in the 19th century so that mercury emissions to the soil were occurring as early as 1898. Investigations have estimated that there is approximately 260-450 tonnes of mercury in the soil and approximately 10 kg of mercury in the groundwater.

3.3.1.4 Summary

Table 3-6 summarizes the known mercury-cell sites, although there is reason to believe there are others not on this list. For example, the questionnaire response from Hungary mentioned two sites closed in the mid-1980s that were not included in other references.

Table 3-6 Decommissioned and operating mercury cell chlor-alkali sites in the EU27+2 (2007)

Country	AU	BE	CH	CZ	DE	DK	ES	FI	FR	GR	HU	IE	IT	NL	NO	PL	PT	RO	SK	SE	UK	Total
No. of sites	2	4	4	2	17	1	10	4	8	1	5	1	13	3	2	3	2	3	2	7	8	102

Source: see Annex 4

Based on Member State responses to questionnaires and other sources (ERM 2000; BREF Chlor-alkali 2001; EEB 2006; Mahan and Savitz 2007; Hylander and Meili 2005), it is possible to estimate roughly how much mercury may be contaminating these various sites. Of the 102 total sites listed here, of which about half have been closed or converted to mercury-free by 2007, it is assumed that about half of those closed or converted sites are cleaned up to such an extent that remaining contamination is negligible. The actual number of “clean” sites may be less, so this is considered a conservative assumption.

Of the remaining 74 sites, while the documents referenced above provide some useful indications, further assumptions must be made about the number that are heavily contaminated (assumed up to half of the sites), lightly contaminated (up to one-quarter) or somewhere in between (again, up to half of the sites). Estimates must also be made of the extent of contamination, which appears to be more closely correlated with the length of time the plant was operating, and with the waste management practices in effect, rather than with the size of the plant.

Table 3-7 Mercury contamination of EU27+2 chlor-alkali sites

Level of contamination	Number of contaminated mercury cell chlor-alkali plant sites		
	Minimum	Maximum	Average
Heavy	22	37	30
Medium	22	37	30
Light	11	19	15
Total	56	93	74
Level of contamination	**Mercury contamination per site (tonnes)**		
	Minimum	Maximum	Average
Heavy	100	400	250
Medium	30	100	65
Light	5	30	18
Level of contamination	**Mercury contamination total EU27+2 (tonnes)**		
	Minimum	Maximum	Average
Heavy	2220	14800	7400
Medium	666	3700	1924
Light	56	555	259
Total	2942	19055	9583

Sources: ERM 2000; BREF Chlor-Alkali 2001; Mahan and Savitz 2007; Hylander and Meili 2005; consultant estimates.

Overall, as shown in Table 3-7, these calculations show a wide range of estimates that could logically be narrowed to some 8,000 to 14,000 tonnes – still reflecting the large uncertainties, with a median total contamination of some 9,600 tonnes of mercury, as in the table.

3.3.2 Former facilities for production of VCM

The acetylene process for the production of VCM, using mercuric chloride on carbon pellets as a catalyst, is a technology that was not widely used in Europe. However, it was well enough known that an OSPAR Convention Decision in 1985 (Decision 85/1) defined recommended thresholds for mercury releases to the aquatic environment from VCM production with mercury catalysts. One plant apparently still operates in the USA, four plants are known to operate in Russia, and there are dozens in China (UNEP 2005). Only one former facility in the EU was reported in response to the questionnaires sent to Member States, as below.

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, etc.)
SE	Sundsvall	12 km^2	23.000 barrels in the Bay of Sundswall	9	Catalyst containing mercury from VCM production

With such limited information as guidance, even if one assumes a range of site contamination of 5-100 tonnes of mercury at 10-30 possible sites throughout the EU27+2, this would give a wide range of 50-3000 tonnes, or more logically in the range of 1000-2000 tonnes of potential mercury contamination at these sites.

3.3.3 Manufacturing sites of mercury-containing products & processes

Again, only one previous manufacturing site was mentioned in questionnaire responses, as below.

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury (tonnes)	Original state of the mercury (pure, compounds, waste, etc.)
BE	Lokeren, Flanders	14,350	Soil: 30,000 m³ Groundwater: 3,729m³	Soil: 1560 Groundwater: 23.7	The town of Lokeren was a well-known centre of the tanning industry. To remove the hair from rabbit skins, they were treated with mercury nitrate.

There is little way of knowing what is the extent of the mercury contamination at former manufacturing sites, although by any measure the contamination at Lokeren seems very high and may have been overestimated. It would be consistent with any standard distribution to assume that a relatively few sites are highly contaminated, while a larger number of sites are less contaminated. It is also assumed that he abandoned sites with the highest contamination is already cleaned up. Furthermore, if one considers the various manufacturing processes and wastes generated, waste disposal practices at the time, the amount of mercury involved, the numbers of products produced in the EU27+2, the number of years different facilities were in operation, etc., one may begin to have a very rough idea of potential mercury contamination in different industry sectors using mercury. The estimates in the following table were developed from such considerations.

Table 3-8 EU27+2 contaminated manufacturing sites – product applications of mercury

Manufacturing activity with mercury	Total sites still contaminated		Average mercury per site (tonnes)		Total mercury (tonnes)	
	Minimum	Maximum	Low	High	Minimum	Maximum
Measuring equipment	10	30	0.4	4	4	120
Batteries	10	20	1	5	10	100
Paints	20	40	1	5	20	200
Electrical components	10	40	0.2	2	2	80
Biocides, pesticides - low	20	60	0.2	1	4	60
Biocides, pesticides - high	5	10	1	10	5	100
Other - low	50	100	0.2	1	10	100
Other - medium	10	30	2	10	20	300
Other - high	2	5	15	150	30	750
Total	137	335			110	1,800

Overall, as shown in Table 3-8, these calculations suggest a wide range of about 110 - 1,800 tonnes, but at the basis of the modest data material, it is not possible to narrow the range

3.3.4 Production and waste sites of the chemical industry

The main mercury contaminated sites of the chemical industry are chlor-alkali sites, as discussed in chapter 3.3.1. Only one other site was mentioned in the country submissions to the request for stakeholder input and the questionnaire, as below.

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, etc.)
DK	Kærgård Plantage, Region Syddanmark	1,500 m2 (known area - might be larger)	5,000 t	2 (proven amount in the known area)	Mercury sulfite from chemical industry

3.3.4.1 Pulp and paper industry

An organic mercury fungicide (phenylmercuric acetate) was used extensively in the pulp and paper industry from the 1940s until at least the 1960s as an anti-slime agent in piping, and as a preservative for the pulp. Large amounts of cellulose fibres were emitted with the process water and this typically accumulated in lakes and rivers in large fibre banks, contaminated with Hg and organochlorine compounds. The four Swedish plants in the table below, showing accumulations up to 750 kg of mercury, have relatively low contamination compared to many other pulp and paper sites in the EU (Hylander and Meili 2005).

Table 3-9 Costs to remediate mercury contaminated sites in Sweden

Site	Hg emitted (tonne)	Hg to secure/ secured (kg)	Total cost (million SEK)	Total cost (million US$)	Cost (US$/kg Hg secured)	Year of cost calculated	Observations
Rolfstaån	2	100 [a]	80 – 100	11 – 13	105,000 – 135,000	1995	640 000 m^3 fibre (paper mills)
Svartsjöarna		15 – 150	100 – 120	15 – 16	98,000 – 1,100,000	2004	260 000 m^3 fibre (paper mill)
Turingen		350	66	9	2,500	2004	225 000 m^3 sediment (paper mill)
Örserumsviken		750	115	15	20,000	2002	1400 kg PCB, 170 000 t sediment (paper mill)

[a] another 300 kg in lake sediments of Kyrksjön and Långsjön
Source: Hylander and Meili (2005)

Nevertheless, because these accumulations are typically in water bodies (except in cases where the sediments have been dredged) rather than on land, they will not be further quantified for the EU region for this analysis.

Otherwise, there would seem to be many sites in the EU27+2 that have engaged in some aspect of the chemical industry with the use of mercury compounds, and the average mercury contamination would be expected to be relatively low. Based in part on the number of manufacturers of chemical compounds identified for Chapter 2.7, and appreciating that this is only one such industry sector, it is estimated that some 50-100 contaminated "chemical industry" sites (not included elsewhere in this inventory) are dispersed around the EU, with mercury contamination ranging typically from very little to 5 tonnes, for a total of some 100-400 tonnes mercury.

3.3.5 Mercury mining and smelting sites

In metal or mineral mining the essential purpose of the processing is often to reduce the bulk of the ore and increase the concentration of the desired mineral, which can be sold as a product or must be transported to and processed by subsequent processes (e.g. smelting), by using methods to separate the valuable (desired) mineral(s) from the gangue. The marketable product of this is called concentrate, and the remaining material (the waste) is called tailings. Within the industrial minerals industry it may also be an objective to create different qualities (purity, grain size etc) of the produced mineral for different segments of the market as the same mineral may have several different applications.

3.3.5.1 Almadén mercury mines

The Almadén mining district, located in Ciudad Real, Spain, occupies only 30 square kilometres but is the largest geochemical anomaly of mercury on Earth. The district includes a series of mercury mineral deposits with a common mineralogy (dominant cinnabar: HgS, and minor pyrite: FeS_2). The ore deposits have been mined for more than 2000 years, and the main mine of the district (Almadén) was active from Roman times with almost no interruptions until its closure in 2003. The mercury distribution in soils of the district reveals the existence of very high mercury content (up to 8,889 µg/g), whereas concentrations in stream sediments and waters may reach 16,000 µg/g and 11,200 ng/l respectively (Higueras *et al.* 2005).

MAYASA, the parent company of Almadén, long intended to build a facility at its mine site for the recovery of mercury from wastes, and began receiving wastes from other countries for that purpose – 84 tonnes from the Netherlands, 4,534 tonnes from Germany, 3,950 tonnes from Italy, 120 tonnes from Norway, etc. However, the waste treatment facility was never built and MAYASA claimed that no wastes were admitted to its dump site after 1987, and that the site has been sealed since 1991. Officially, the dump site contains just over 8,000 tonnes of waste containing an estimated 200-400 tonnes of mercury.

3.3.5.2 Idrija mercury mine, Slovenia

At the Idrija Hg mine in Slovenia, thousands of tonnes of Hg have been released to the atmosphere, surface waters and the soil over more than 500 years. The following contamination was reported by Slovenia in response to the questionnaire.

	Location	Area of contaminated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, etc.)
SL	Idrija	17,000		more than 10 mg/kg	Previous mining & smelting activities
	Flooding area of the river Idrija	10,000		more than 10 mg/kg	Previous mining & smelting activities
	Tržič (Sv. Ana)	5,000		more than 10 mg/kg	Previous mining & smelting activities

According to Horvat (2006), an area of 32,000 m^2, as above, is contaminated at more than 10 mg/kg from former mercury mining and smelting activities. This area had a long history. It is estimated that in the initial mining activities in the Idrija Mercury Mine (1490-1508) about 180 tonnes of commercial Hg were produced as well as 180 tonnes of Hg lost to the environment, mostly to the River Idrijca. During the period 1509-1785 the smelting recovery was around 65% and the mine produced 24,074 tonnes of commercial Hg. The Hg ore was smelted at several locations around Idrija until 1652, when a new smelting plant was built on the left bank of the River Idrijca. Smelting residues were discarded into the river. It is estimated that in that period around 13,000 tonnes of Hg were lost to the environment, mostly to the atmosphere and into the River Idrijca. During the period 1786-1945, another 59,350 tonnes of commercial mercury were produced. After 1868, smelting facilities were gradually moved to the right bank of the river, and up to the end of the Second World War the smelting furnaces were changed several times. During that period mercury recovery was about 75%; most of the lost mercury (around 20,000 tonnes) was released to the atmosphere, while some permeated into the soil or was dumped as a by-product into the river.

During the period 1946-1960, a further 6,693 tonnes of commercial Hg were produced. The smelting recovery was around 85%. During the period 1961-1977, yet another 9,230 tonnes of Hg were produced. During the period 1963-1968 new modern rotary furnaces were built and the smelting recovery increased to 92 %. Smelting residues then contained 0.005% of Hg. In 1977 the mine was temporary closed; the production stopped, but started again 1983. During the period 1983-1995, 547 tonnes of commercial Hg were produced. During the full period 1960-1995 about 243 tonnes of Hg were lost into the environment. Of that amount, 168 tonnes of Hg were deposited in landfill as smelting residue, 60 tonnes were emitted to the atmosphere in flue gases, and 15 tonnes of Hg were released to the River Idrijca in condensation water. In 1995 the last rotary furnace ceased operation (Horvat 2006).

Unless large pools of mercury are at some time identified in the river, any non-mine mercury recovered from this area would come from the smelting residues, which would be relatively expensive to process merely for the purpose of obtaining mercury.

3.3.5.3 Italian mercury mines

Monte Amiata (Tuscany region, central Italy) is a mountain of volcanic origin, rich in ore containing mercury sulphide, or cinnabar (HgS). Mercury extraction started before the Roman era, and “modern” mining activity began in 1847. It developed to a larger scale at the beginning of the 1900s and the mercury production in the district rapidly became among the most important in the world. The ore has a mercury content of 0.6 to 2.0%, and was extracted from pits up to 400 meters deep. Several independent mines (up to 42 in 1948) were active in the same area, but the ore was treated by only a few smelter works. During the second part of the 1900s, most of the small mines were closed and those remaining were eventually taken over by one company.

The main smelter works in the area were situated near the major mine at Abbadia San Salvatore. Metallic mercury was produced through ore-roasting from 1893 until 1976, when the mining was stopped. Mercury production continued for several years through the use of secondary sources like sludge wastes, but in 1983 all activities ceased. At the end of the 1960s the annual production was about 1200 tonnes of mercury, decreasing to 850 tonnes by 1973 (Bellander *et al.* 1998).

Details of local contamination in the form of mining and smelting wastes and residues are not readily available, although based on indications from Almadén and Idrija, mercury contamination is likely to be at least 200 tonnes.

3.3.6 Other mining and smelting sites

Other metal ores that typically have elevated trace mercury content include primarily zinc, copper and lead ores, all of which are mined and processed in significant quantities in the EU.

A compilation of Hg in industrial waste in Sweden suggests 280 t of Hg in 5,000 t of mining waste containing more than 1% Hg (held for deep bedrock storage), 800 t of Hg in mining waste with 0.0001–1% Hg, 8 t of Hg in steel industry waste containing about 0.0004% Hg, 8 t of Hg in waste from the paper and pulp industry containing about 0.0007% Hg, and 13 t of Hg in deposits at former chlor-alkali and paper pulp factories (Swedish EPA 2001).

It has been calculated in section 3.2, that some 300-370 tonnes of mercury are contained in non-ferrous ores and concentrates that are refined annually in the EU. It is reasonable to assume that only a few percent of that quantity now remain in mine tailings that annually contaminate mining sites, and that efforts are made in operating mines to limit environmental hazards of tailings. However, contamination from closed mines that were operated before stricter controls could be considerable, and probably amount to several times the annual mercury content of refined ores, hence an estimated 1,000-1,500 tonnes of mercury.

Non-ferrous smelters, and to a lesser extent ferrous smelters, are known to have been significant emitters of mercury to the atmosphere, but the quantities of mercury remaining in wastes at smelting sites are far less significant than the mercury in tailings at mining sites. Therefore they will not be quantified here.

3.3.7 Unusual contamination

A more unusual site is a contaminated area of 30,000 m^2 around a German submarine under 150 meters of water off the coast of Norway with about 65 tonnes of metallic mercury, as reported in the Norway response to the questionnaire.

3.4 Summary

According to Hylander & Goodsite (2005), the cost of site remediation is such that each kg of mercury recovered could typically cost at least 50-100 times the present market price of mercury. Nevertheless, it could be estimated that perhaps 10-30% of the contamination could be removed at a somewhat lower price, while another part of the mercury contamination would be much more costly to remove.

It should be noted that where liquid mercury can be easily collected, the cost of such collection would probably not be much higher than the present market price of mercury. For example, at the Priolo chlor-alkali site in Italy, which was closed at the end of 2005, some of the process mercury has been transferred from the site, but another part of it remains on site. The total amount of relatively easily recoverable mercury is probably not more than 10% of the total contamination of most types of sites. Otherwise, except in the case of by-product mercury, it is safe to conclude that the cost of securing mercury at virtually all of these sites considerably outweighs the present market value of the mercury that could be recovered.

Table 3-10, summarises the mercury contamination at the various categories of sites discussed in this chapter, arriving at a range of some 11,000 to 20,000 tonnes of mercury, of which no more than 10% could perhaps be economically viable to recover at a market price for mercury up to two times the present price.

Table 3-10 Contaminated sites in the EU27+2

Sites	Mercury contamination (tonnes)		% mercury viable re-covery	Mercury viable (tonnes	
	Minimum	Maximum		Minimum	Maximum
Chlor-alkali	8,000	14,000	10%	800	1,400
VCM manufacturing	1,000	2,000	10%	100	200
Production of mercury products and other processes	110	1,800	10%	11	180
Other chemical industry	100	400	10%	10	40
Mercury mines and smelters	500	700	5%	25	35
Other mines and smelters	1000	1500	0%	0	0
Total (round)	11,000	20,000		900	1,900

4 Mercury waste handling

4.1 Overview of the waste management situation

An overview of community legislation pertinent to the different mercury-containing waste fractions is shown in Table 4-1 overleaf. Most waste fractions of mercury-containing products are considered hazardous waste regardless of the mercury content, whereas several of the mercury-containing waste entries (indicated with an (M) in the table) are considered hazardous waste only if dangerous substances are present above a certain threshold concentration.

Specific regulations pertinent to the collection of mercury-containing products apply to mercury-containing lamps (WEEE Directive), batteries (Battery Directive), switches and lamps in vehicles (ELV Directive), and switches, relays and other mercury-containing components in electrical and electronic equipment (WEEE Directive). For each of the waste fractions there is a specific entry in the European Waste Catalogue, and in principle it should be possible to obtain an overview of the waste management situation across the EU for these waste categories.

The Member States are obliged, in accordance with the Regulation No 2150/2002 on waste statistics, to keep registers of the waste generated and the disposal method, but data on the individual waste entries are not generally available at community level. As part of this study the Member States have been requested by use of a questionnaire to provide information on the generation and disposal of mercury-containing waste. However, only a few Member States submitted detailed waste data, suggesting that knowledge or concern about these wastes is limited, and it has therefore not been possible to provide an overall view of the waste management situation for the different fractions.

The focus of the following description of the waste management situation is the waste originating from intentional use of mercury in products and processes. In order to put the mercury quantities in these waste fractions into perspective, initially country examples of the total amount of mercury in all waste are presented.

The description of the waste management situation for the different categories of waste from intentional uses of mercury has been presented in specific sections for application area in Chapter 2. The description is mainly based on the questionnaire responses, previous studies of waste management in the EU and statistics from trade organisations.

The description is followed by a discussion of mercury recycling paths and rates in section 4.2, and a list of options for future community wide actions as regards mercury waste management in section. 4.3.

Member State legislation on mercury waste management and treatment going beyond current community legislation is described in the section 5.2.

Table 4-1 Mercury waste fractions, pertinent community legislation, and European waste catalogue categories

Waste fraction	Pertinent community legislation		European waste catalogue entry
	Collection	Disposal	
Product wastes			
Mercury-containing lamps including lamps in EEE	WEEE Directive	Hazardous waste directive	20 01 21 fluorescent tubes and other mercury-containing waste
Mercury-containing batteries	Battery Directive	Hazardous waste directive	16 06 03 mercury-containing batteries
Mercury in older alkaline batteries	Battery Directive	Hazardous waste directive	16 06 04 Alkaline batteries (M)
Dental amalgams		Hazardous waste directive	18 01 10 amalgam waste from dental care
Measuring and control equipment (non EEE)		Hazardous waste directive	20 01 21 fluorescent tubes and other mercury-containing waste
Mercury switches and lamps from vehicles	ELV Directive	Hazardous waste directive	16 01 08 components containing mercury from end-of-life vehicles from different means of transport (M)
Mercury switches, relays, thermostats, etc.	WEEE Directive	Hazardous waste directive	20 01 21 fluorescent tubes and other mercury-containing waste
Laboratory chemicals		Hazardous waste directive	16 05 06 laboratory chemicals, consisting of or containing dangerous substances, including mixtures of laboratory chemicals (M)
Miscellaneous uses		Hazardous waste directive	20 01 21 fluorescent tubes and other mercury-containing waste 16 02 13 Discarded equipment containing hazardous materials
Waste management/crematoria			
Crematoria (from dental amalgams)	Atmospheric emissions…	Hazardous waste directive	10 14 01 waste from gas cleaning from crematoria containing mercury (M)
Waste incineration (from batteries, thermometers, lamps, etc,)	Waste Framework Directive	Hazardous waste directive	19 01 05 filter cake from gas treatment in Waste Management Facilities (M) 19 01 10 spent activated carbon from flue-gas treatment Waste Management Facilities (M)
Process wastes			
Mercury waste from chlor-alkali plants		Hazardous waste directive	06 07 02 Activated carbon from chlorine production (M) 06 07 99 Other wastes from chlorine manufacture (M)
Mercury in industrial wastewater – chlorine		Wastewater Directive	06 05 02 Sludges from on-site wastewater treatment – inorganic chemical processes (M)
Mercury in industrial wastewater – pharmaceuticals		Wastewater Directive	07 05 11 Sludges from on-site effluent treatment – pharmaceuticals (M)

Waste fraction	Pertinent community legislation		European waste catalogue entry
	Collection	Disposal	
Mercury in industrial wastewater – fine chemicals		Wastewater Directive	07 07 11 Sludges from on-site effluent treatment – fine chemicals (M)
Mercury in polyurethane elastomer production wastes		Hazardous waste directive	07 02 08 Halogen free residues from reaction and distillation of polymer and rubber industry (M)
Mercury wastes from production of chemical compounds		Hazardous waste directive	06 04 04 Mercury-containing waste from processes of inorganic chemistry (M)
Mercury wastes from metal treatment operations		Hazardous waste directive	11 01 16 Saturated or spent ion exchange resins – metal treatment (M)
Mercury removed from process gases		Hazardous waste directive	19 01 05 Filter cake from gas treatment (M)
Mercury removed from process exhaust or flue gases		Hazardous waste directive	19 01 10 Activated carbon from exhaust/flue gas treatment (M)
By-product and other wastes			
Mercury as natural contaminant in gas		Hazardous waste directive	05 07 01 wastes containing mercury from natural gas purification and transportation (M)
Mercury adhering to special catalysts used for purification of natural gas		Hazardous waste directive	16 08 07 Used natural gas cleaning catalysts (M)
Mercury in waste from metallurgical activities including Hg -selenium waste from zinc production (1)		Hazardous waste directive	06 04 04 wastes containing mercury in metal-containing wastes other than wastes from the Manufacture, Formulation, Supply and Use (MFSU) of salts and their solutions and metallic oxides (M)
Hg-selenium waste from zinc production (2)		Hazardous waste directive	06 03 13 MFSU of solid salts and solutions containing heavy metals (M)
Generation of calomel during the zinc refining process		Hazardous waste directive	10.05 99 Smelting wastes – zinc (calomel)
Mercury waste produced during the lead refining process		Hazardous waste directive	10 04 99 Smelting wastes – lead (M)
Mercury waste produced during the copper refining process		Hazardous waste directive	10 06 99 Smelting wastes – copper (M)
Mercury contaminated building materials		Hazardous waste directive	17 09 01 construction and demolition wastes containing mercury (M)

Note: (M) Hazardous waste only if dangerous substances are present above threshold concentrations.

4.1.1 Mercury quantities in waste

Based on the descriptions of the waste handling situation for the different product categories in chapter 2, a summary on mercury in waste originating from intentional uses of mercury is presented in Table 4-2.

Table 4-2 Mercury in waste from intentional uses of mercury

Products category	Quantities ending up in waste, tonnes Hg	Quantities recovered, tonnes Hg	Percentage of total recovered	Recycling efficiency, %
Chlor-alkali production	119	35	34	29
Light sources	14	1.6	2	11
Batteries	30	4	4	13
Dental amalgams	95	30	29	32
Measuring equipment	21	4.5	4	21
Switches, relays, etc.	14	7	7	50
Chemicals	41	6.5	6	16
Miscellaneous uses	70	13	13	19
Total (round)	404	102	100	25

In order to put the mercury from intentional uses in waste into perspective, country examples of the total mercury flow with wastes is described in the next section.

4.1.2 Mercury quantities in waste, country examples

Germany
The total quantities of waste fractions containing mercury in Germany in 2005 are shown in Annex 2. In total, 32,600 tonnes of waste was generated. The major waste fractions with relatively low mercury concentration such as waste from inorganic-chemical processes, demolition of buildings, filtercake waste from flue gas cleaning in incineration and used alkaline batteries were mainly landfilled. Combustible waste fractions, mainly pesticides from collected fractions of municipal waste and activated carbon or filtercake waste from flue gas cleaning in incineration or pyrolysis of wastes, were almost exclusively incinerated. In other Member States with less capacity for incineration these fractions may likely be landfilled. Recovery operations are reported for fluorescent tubes and other mercury-containing waste and a part of the batteries and mercury-containing waste from inorganic-chemical processes. Of the waste fractions with mercury-containing products, the 14,300 tonnes of fluorescent lamps represent by far the major part of the waste in terms of waste tonnage.

Germany is the main import country for mercury-containing waste. As shown in Table 4 6 in section 4.1.3 on transboundary movement of mercury-containing waste, import to Germany accounted for 50% of the total mercury transboundary transport between the Member States in 2003 and Germany received mercury waste from 14 other Member States.

In 2005 Germany imported 7,192 tonnes of mercury-containing waste, mainly fluorescent tubes and mercury-containing waste from processes of inorganic chemistry (.

Table 4-3). As no information on the mercury content of the waste is available, the waste quantities do not necessarily reflect the distribution between waste categories in terms of mercury.

Table 4-3 Import and export of mercury-containing waste in Germany 2006 (Germany questionnaire response)

EWC-code	Type of Mercury-containing waste	Import (tonnes)	Export (tonnes)
05 07 01	Mercury-containing waste from cleaning of natural gas	920	0
06 04 04	Mercury-containing waste from processes of inorganic chemistry	2,665	0
06 05 02	Slags from wastewater treatment after inorganic processes, containing hazardous substances	13	0
07 02 08	Halogen free residuals from reaction and distillation of polymer and rubber industry	139	0
10 14 01	Mercury-containing waste from waste gas cleaning in cremation	9	0
16 02 13	Other hazardous fractions of used equipment	6	0
16 06 03	Mercury-containing batteries	2	0
17 04 09	Metal waste, contaminated by hazardous substances	25	0
17 09 01	Mercury-containing waste from building demolition	218	0
18 01 10	Dental amalgam waste	9	16
20 01 21	Fluorescent tubes and other mercury-containing waste	3,552	117
Total		7,558	133

For some of the fractions information on the mercury content is available and Table 4-4 shows waste quantities and mercury quantities from certain industrial processes and product groups in Germany around 2005.

The main source of mercury with waste in Germany is chemical processes (mainly chlor-alkali) with 72 tonnes of mercury either safely deposited or landfilled in 2003. Waste generation from chlor-alkali in other Member States is discussed in section 2.1.5. It is notable that the management of 7,000-9,000 tonnes of fluorescent lamps only represented 0.35 tonnes of mercury that was ultimately landfilled. The total mercury content of 70 tonnes dental amalgam waste was 2-3.5 tonnes (3-5% Hg in the waste) which is a much lower concentration than is estimated for dental amalgam waste in other Member States. The differences may reflect actual differences in the waste composition as discussed in section 2.4.6.

The total mercury content of Germany's domestic waste (originating from mercury-containing products) is estimated at 2.4 tonnes based on an average mercury content of 0.12 mg/kg. It should be noted that this content is about 10 times lower than the concentration reported in other countries, e.g. 1.6 mg/kg in Finland (Table 4-5) and 0.8-1.4 mg/kg in incinerated MSW in Denmark (Christensen *et al.* 2004). The question regarding mercury in the general domestic waste is essential in understanding the efficiency of the separate collection of mercury-containing waste fractions. It has not been possible to clarify the cause of this discrepancy, but there may even be a difference between the German definitions of "domestic" vs. "municipal" waste as these statistics were compiled.

Table 4-4 Mercury-containing wastes from certain industrial processes and product groups in Germany around 2005 (Germany, stakeholder consultation 2005)

Waste fraction	Tonnes of waste	Tonnes of mercury	Note
Fluorescent lamps and mercury vapour lamps	7,000-9,000	0.35	Recovered material is usually landfilled
Dental amalgam waste	70	2 - 3.5	Recovered mercury used for battery production
Used batteries	700		-
of this - used button cells	76	5	Includes button cells that had been stored
Waste from chemical processes (mainly chlor-alkali)	6.500	72	35 t Hg safely deposited, 35 t Hg landfilled in 2003
Domestic waste	20 million	2.4	1.2 t Hg incinerated, 1.2 t landfilled
Total (round)		82 - 84	

Finland

A summary of mercury quantities in waste in Finland in 2000 is shown in Table 4-5. The country is unique due to the large mercury quantities in waste from zinc production that account for 96% of the mercury in waste in the country. Mercury recovered as a by-product of zinc production is described further in section 3.2.1.

The quantities of mercury from products may quite well be significantly lower today compared to the situation in 2000, but it is still notable that mercury in measuring and control equipment (0.4 tonnes), thermometers (0.2 tonnes) and electrical and electronic waste (0.3 tonnes) is nearly of same magnitude as batteries (0.5 tonnes, perhaps only mercuric oxide batteries), amalgam (0.5 tonnes) and light sources (0.23 tonnes). The total amount of mercury in the municipal waste was 2.2 tonnes.

Table 4-5 Summary of mercury quantities in waste in Finland 2000 (Finland, stakeholder response 2005)

Type of waste	Annual quantity tonnes		Hg-content	Treatment	Recycling Rate(%)
	Hg	Waste			
Hg from zinc production waste sludge distillation	79	79	100 %	Distilled pure Hg, exported.	96
Waste sludge from zinc production (Hg distilled)	0.04	125	300 ppm (0,03%)	Deposited to special landfill.	
Sludge from copper production	0.09	80	0,11 %	Product re-used in zinc factory	
Jarosite from metal production	0.28	200.000	App. 1,4 ppm	Deposited in landfill.	
Filter dust from steel works		3.000	?	Deposited to landfill.	
Waste from chloralkali industry:					
- Ashes from distillation of waste sludges	0.06	2…3	5…40 ppm	Deposited to special landfill.	
- Hg-containing waste, not treatable		app. 1,0	variable	Deposited to special landfill.	
Amalgam waste	0.5	1,0…1,2	30…35 %	Distilled Hg is exported.	80
Hg-containing batteries	0.5	app. 1,0	50 %	Collected and exported for treatment.	50
Thermometers	0.2			Metallic Hg recovered mechanically. 10 % of total waste amount ends up at landfill sites.	90
Light sources	0.23		variable	Treated / landfilled among municipal waste.	50
Measuring and control instruments	0.4			Hg is separated from equipment before landfill deposition.	nearly 100
Electric and electronic waste	0.3			Hg is separated from equipment before landfill deposition.	
Sewage sludge	0.3	150,000	1,9 ppm (estimated)	Used in park and agricultural areas or deposited to landfills.	
Residues from incineration of fossil fuels	0.25	200,000	very low	Used as filling material.	
Medical waste		not estimated	low level, variable		
Municipal waste	0.224 *1	1,400,000	1,6 ppm (estimated)	Deposited to landfills (amount not included in previous figures), minor amount incinerated.	
Sludge from treatment of Hg-containing waste	0.03	10	0,28 %	Disposed into special waste landfill.	
Total	82.4				
Total (excl. waste from zinc production)	3.4				

*1 Authors' comment: Seems to be miscalculated: 1.6 ppm in 1.4 million tonnes would be 2.24 tonnes

4.1.3 Transboundary movement of mercury-containing waste

Mercury waste is moved between Member States in large quantities.

Export of mercury waste from Member States as reported to the Basel Convention Secretariat is shown in Table 4-6. The full dataset for 2004, including the disposal or recovery method, is shown in Annex 3. The total quantity of imported waste was 7,192 tonnes with Germany (3,890 tonnes) and Belgium (1,474 tonnes) as the main import countries. Germany received mercury waste from 14 other Member States.

For the reporting to the Basel Secretariat all mercury waste is included in one category and it is not possible to break down the data into different types of mercury waste.

The quantities of mercury in the waste are not indicated in the data reported to the Basel Convention Secretariat.

Table 4-6 Import/export of waste category Y29, "Wastes having as constituents: Mercury; mercury compounds" in 2003 as reported by the exporting country to the Basel Convention Secretariat

Country of export	Country of import, tonnes														
	AT	BE	CH	DE	DE, LT, USA	DK	ES	FR	GB	LT	LV	NL	NO	SE	UA
AT				127											
BE-FL				181								15			
CZ	0														
DE	10								5						
DK		146		317								4		2	
EE															29
ES				7											
FI	1			16											
FR	9	487		202								933			
HU				791											
IE		20		17					12			33			
LT *											36				46
LU		54		16				86							
LV										0					
NL		648	3	2087											
PL					290										
PT		1		10			65								
SE				11		101						10	138		
SI				20											
UK		118		88											
Total	20	1474	3	3890	290	101	65	86	17	0	36	995	138	2	75

* Reported to be 1000 times higher, but it is assumed to be a decimal error by the reporting as discussed in Annex 6

4.2 Recycling paths, rates and projections for the future

4.2.1 Primary waste streams for recycling

The four key mercury waste streams that lend themselves to recycling comprise:

- Waste associated with the intentional use of mercury in products, preparations, mixtures, etc. – their fabrication, use and disposal. These uses are the main focus of this study, and have been discussed in detail in previous chapters.

- Waste produced by mercury cell chlor-alkali plants during normal operation and at decommissioning (when the plant is either converted to a mercury-free process or sometimes closed if no longer economically viable). These wastes may consist of sludges, filter cake, construction materials, activated carbon, etc.

- Waste produced as a result of other process uses of mercury in chemical or other manufacturing processes. These wastes may consist of catalysts, sludges, filter cake, activated carbon, etc.

- Waste associated with by-product mercury that occurs in the smelting and refining of some ferrous and most non-ferrous metals (especially zinc, lead and copper), and from the purification of natural gas. These wastes may consist of catalysts, sludges, filter cake, activated carbon, etc.

4.2.2 Processes used for recycling of mercury

There are four primary methods for recovering mercury from products and wastes, other than physically pouring the mercury out of a device when possible:

- The thermal process;
- The pyrometallurgical process;
- The hydrometallurgical process;
- The electrometallurgical process.

4.2.2.1 The thermal process

Most mercury wastes are treated using a thermal process in which mercury vapour is generated and then collected by condensation. In this case, the mercury-containing waste materials are first sorted and a mechanical treatment recovers as much of the mercury as possible. After sorting, the vacuum-thermal demercurisation process requires that the waste be charged into an enclosed chamber. The mercury content of the waste is then evaporated at temperatures ranging between 340 and 650°C and pressures of few millibar, and recovered in metallic form after condensation at lower temperatures. Organic components are oxidized as required in an oxygen-rich burning chamber at temperatures ranging from 800°C to 1000°C. The residue that remains at the end of the vacuum-thermal process is essentially mercury-free and, depending on its composition, is either recycled or disposed of safety. The metallic mercury is then refined to the necessary quality via a multi-stage cleaning/distillation process and brought to market (GMR 2008).

4.2.2.2 The pyrometallurgical process

A somewhat more sophisticated pyrometallurgical recycling process may be used for the treatment of special wastes such as naturally radioactive slurries coming from the natural gas industry. This process ensures dust-free treatment of these wastes and is designed for smaller batches.

The demercurisation takes place in a vacuum-sealed, double-walled mixer, using thermal oil with a maximum temperature of 340°C as the heating medium. For particulate removal a high efficiency vapour filter is used. Via fractional distillation separate recovery of water and contaminated samples (hydrocarbons/mercury) is possible. The cooling/conditioning of the mercury-free residue then takes place in an integrated cooling mixer connected via vacuum to the heating mixer. For the removal of the mineral residues a discharge screw is used. The intensive mixing during distillation guaranties an optimal energy exchange and ensures a short energy-efficient treatment (GMR 2008).

4.2.2.3 The hydrometallurgical process

Mercury-containing chemical compounds and solutions must be pre-treated in order to recover mercury. A wet chemistry technique may accommodate mercury salts, acids and alkaline solutions. Typical processes combine a series of batch reactors, using reagents, catalysts, etc., to separate mercury from metal bearing wastes in solution or from solids. The base solutions are also purified for recovery. Processes include batch reactors and other reactor or filtration systems. The mercury wastes are dissolved in strong acids and then subjected to selective precipitation or ion-exchange reactions to separate the various metals and compounds from other residues. Metals separated in these processes are further recovered in the mercury retort system.

4.2.2.4 The electrometallurgical process

An electrical charge is frequently used to remove simple oxidation from metallic mercury. In a more complex process that is an “electro” version of the “hydro” process above, a heavier charge may be used to generate ions in an alkaline solution that then serve to remove mercury from compounds and solutions in various liquid wastes.

Recycling processes may be designed so that virtually all mercury emissions are collected through a mercury recovery air filtration system, minimising any discharges to the outside atmosphere. There may be several banks of carbon filters in the air filtration system, in which activated carbon is designed specifically to remove mercury from the air stream. Large blower fans may be used to create a slight negative pressure throughout the entire work area so that any fugitive emissions can be captured by the carbon in the air filtration system.

4.2.2.5 Lamp recycling

There are two main methods for removing mercury from fluorescent lamps (Huisman *et al.* 2007). One method is to cut the end(s) off the glass tube of the lamp and remove the mercury and phosphor powder. The second method is to shred the lamp and then mechanically separate out the powder, typically in one of two ways:

- The fluorescent tubes may be crushed, sieved and separated, producing a fluorescent powder, glass and metal. The powder is heated under vacuum while simultaneously supplying oxygen to the afterburner. By varying the vacuum pressure, mercury can be extracted from the powder and collected in condensers. Approximately 99% of the mercury can be recovered;

- Alternatively, while the fluorescent tubes are crushed, a filter can trap the mercury vapour that can then be either disposed of or sent for recycling. The glass can be used to make other glass products, and the end pieces (normally consisting of either brass or aluminium) of the tubes can be sold on to scrap metal processors.

4.2.2.6 Battery recycling

Batteries with a significant mercury and/or silver content (i.e., silver oxide or mercuric oxide) are generally treated with the thermal process described above. Batteries with a very low or zero mercury content (e.g. zinc air, zinc carbon, alkaline manganese) may alternatively be treated with a hydrometallurgical (wet chemical) process (ERM 2006).

4.2.3 Recycling practices and pathways

A summary of mercury product recycling in the EU27+2 has been presented in section 2.9. In addition, the few countries that provided detailed recycling information in response to the project questionnaires are mentioned above in section 4.1. Finally, the following table provides a broader overview of recycling practices throughout the EU.

Table 4-7 Member States' responses to diverse Stakeholder questions posed by DG ENV - September 2005 (unless source is otherwise indicated)

Country	Comments submitted
Austria	As of 2004, no Hg recycling reported except dental waste. For dentists an amalgam recovery system is mandatory. The amalgam is recycled in Austria (recovery of Ag and Hg) by a specialised company. Batteries are collected and disposed of in municipal or hazardous waste incinerators. Hg waste is treated and disposed underground.
Belgium (Flanders)	Batteries are collected and recycled (button cells and "black mass" from the treatment of alkaline batteries are treated in Wallonia). In 2004 approx. 7.46 t of mixed button cells were collected in Belgium. According to recent experience, from 1000 kg of button cells, approximately 200 kg of mercury can be recovered, 750 kg of scrap and the rest is mainly consisting of organic material. In 2004 approx. 1515 tonnes of alkaline batteries were collected in Belgium. These batteries are crushed, the metal and other fractions are recovered, and approximately 61% of the collected weight makes up the so-called "black mass." This is rich in zinc, manganese and carbon, and contains approximately 170 ppm Hg. [Therefore, the concentration of Hg by weight is 104 ppm of the total weight of the collected alkaline cells.] The concentration of Hg in the black mass is showing a downward evolution as less and less mercury occurs in the collected batteries.
	Most of the dental amalgam collected (legally required) in Flanders is treated in installations in the Netherlands and Germany to recover silver and mercury. 19 t of dental waste was collected in 2002, 7.5 t in 2003, and 2.6 t in 2004.
	In Flanders there is one installation for the recycling of metallic mercury by vacuum distillation, treating waste from third companies, e.g., fluorescent powder from treatment of fluorescent tubes, thermometers, button cells, and mainly mercury-containing wastes from the chlorine industry. The recovered mercury is sold mostly to the chloralkali-industry. There is also another installation treating mercury-containing lamps in Flanders. Together the two facilities can treat approximately 2200 + 300 tonnes of mercury-containing lamps/yr, many imported. Belgium imported for recycling 1060 t of Hg lamps and waste in 2002, 1130 t in 2003, and 1362 t in 2004.
	Two Belgian chlor-alkali plants export their waste. One chloralkali plant has an installation for some mercury waste distillation. The recovered mercury of this installation is used internally by the industry. In 2002 Belgium exported 38 t mixed Hg waste (mostly chlor-alkali and lamp waste) to Germany for disposal and 16 t "graphite" waste for recycling. In 2003 no recorded chlor-alkali waste was exported. In 2004 Belgium exported 51 t Hg waste (mostly chlor-alkali and lamp waste) to Germany for disposal and 10 t "graphite" waste for recycling. Besides the chlor-alkali waste, lamps, etc., in 2004 over 100 t of filter cake and slag/dust waste containing Hg was also sent to Germany for disposal.
	In Flanders crematoria are subjected to legislation concerning emissions to air with emission limit val-

Country	Comments submitted
	ues and measuring obligations for mercury. From the flue gas wastes, mercury is recovered by distillation.
Cyprus	(In 2004?) 180 t of mercuric oxide batteries were imported, about 30% Hg, therefore 54 t mercury, no incineration, no recycling, all battery waste landfilled.
Czech Republic	Most Hg wastes are recycled, esp. batteries, lamps, construction wastes, vehicles, dental waste. Recycled and recovered Hg put on the market was 17 t in 2001, 19.4 t in 2002, 14.1 t in 2003 and 17 t in 2004.
	0.1 t Hg waste generated from gas cleaning in 2002, and 0.2 t waste in 2003.
	In 2004 there were 197 t of batteries collected, 90% of which have less than 250 ppm Hg.
	There is one Czech producer of thermometers, using about 0.9-1.0 g Hg per thermometer. Including imports of 185,000 thermometers, total use in 2004 was about 200,000 thermometers of all types.
	There are 6,500 dental clinics and labs. More than 50% have mercury separators with an assumed 95% effectiveness at end 2004.
	Two chlor-alkali sites contaminated, with estimated 472 t Hg in buildings and soil – not including electrolytic cells.
Denmark	In Denmark an estimated 20-30% of the button cell consumption was collected separately in 2001, while the number was higher - an estimated 30-60% - for larger alkali batteries (Hansen and Hansen, 2003). The remaining parts of the batteries were expected to be disposed of with household waste, of which most ended up in waste incineration.
Finland	In 2000 recovered 79 t Hg from zinc refining
	Mercury HgO batteries are exported to Switzerland. Annual collected amount in year 2000 was about 1 t containing 0,5 t Hg. Est. 50% collection rate.
	EEE recycling system was introduced in August 2005
	Hg from Boliden Kokkola Oy distillation of amalgam (0,5 t/y) was exported 2000
	Hg from thermometers and meas. & control instruments also recovered, less than 1 t/yr.
	Boliden Kokkola Oy is the only company that exports Hg from Finland
France	2004 amalgam waste containing 15-20 t Hg [compared to Hg demand estimated at 35 t Hg, although that may be total amalgam, containing 17.5 tonnes Hg] Only two facilities in France recycle dental amalgam waste, no indication how much.
	12 million thermometers in households, containing 24 t Hg. Estimated replacement by Hg-free thermometers at the rate of 10%/yr (in hospitals).
	Also significant Hg trapped in hospital wastewater pipes
	24-25,000 t of batteries disposed/yr. Hg content decreasing from 250 ppm in 1998 to 40-70 ppm 2005. About 9200 t batteries recycled in 2003, i.e., about 1 t Hg recovered (~109 ppm).
	Household barometer disposal 4 t Hg/yr about 2000.
	47 million Hg lamps disposed/yr (ref 2000), equal 2-3 t Hg, i.e., about 50 mg/lamp. Lamps are supposed to be separated and recycled since then.
	Chlor-alkali plants contain 3-4,000 t Hg in 2000. They create solid waste containing about 25 t Hg, of which 20 t is recycled and re-used on site, 5 t disposed.
Germany	Hg lamps, 35-45 million collected @ 0.2 kg/lamp = 7-9,000 t/yr collected. Est. 10 mg Hg/lamp = 400 kg Hg (probably more like 20 mg/lamp) in the lamps, most of which are landfilled after collection.
	76 t of button cells collected and recycled in 2004 (and from previous storage) containing 5 t Hg, approx. 6.6% Hg content. Also 700 t other "batteries containing Hg" were collected, but no indication of Hg content.
	70 t/yr dental amalgam waste collected, recycling company est. 3-5% Hg, therefore 2-3.5 t Hg recovered from recycling.

Country	Comments submitted
	About 10 t waste exported annually to Austria.
	6,500 t/yr chemical industry waste, mostly chlor-alkali, average Hg content 0.5%. German submittal translates that to 35 t Hg final disposal and 37 t Hg landfilled in 2003. [But the numbers provided give 30-35 t Hg total, not 72 t Hg.]
	Mercury content in municipal wastes in Germany is 0.12 g/t [3]. Of the 20 Mio. t/a domestic wastes in Germany, 10 Mio. t are incinerated and the other 10 Mio. t are landfilled. The total amount of mercury is approximately 2.4 t Hg/a. Therefore approximately 1.2 t Hg are incinerated and 1.2 t Hg are landfilled above ground
	400-450,000 cremations/yr. Most flue gases treated, no information about Hg recovery.
Hungary	Collected 38 t of battery waste in 2003.
	Collected 340 t of lamp waste in 2003. Some waste “recycled within the [lamp] production facility.”
Netherlands	If mercury wastes are contaminated with other substances like mercaptans, volatile aromatic hydrocarbons or other hydrocarbons, land filling is no option. In these cases mercury and the other volatile compounds are preferably separated from the waste by distillation. Examples of these wastes are sludge from natural gas cleaning, activated carbon from cleaning waste gases and waste waters.
	Sludge from natural gas cleaning assumed to contain 2% Hg (sludge mostly dry from Thailand has about 13% Hg). 700 t sludge in 2002 = 14 t Hg. 900 t sludge in 2003 = 18 t Hg. Filtercake from natural gas cleaning assumed to contain 40% Hg. 17 t in 2002 = 7 t Hg. 14 t in 2003 = 6 t Hg.
	Dental amalgam and amalgam waste assumed to contain 50% Hg. - 6 t waste in 2002 = 3 t Hg. - 4 t waste in 2003 = 2 t Hg. Other dental waste 3-5% Hg = 117 t waste 2002, 131 t waste 2003.
	Hg-Se residue from zinc production contains 5-40% Hg. [No indication how much zinc production in NL.]
	“Metallic” mercury waste 1.4 t in 2002, and 15.9 t in 2003.
	Measuring & control equipment estimated to contain 1-15% Hg. 9.1 t in 2002 could yield up to 0.5 t Hg. 7.7 t in 2003 would be somewhat less.
	46 t Hg lamps collected in 2000, 53 t est. 2006, 58 t est. 2012.
	In the Netherlands collection efficiency across all battery types estimated at about 50-70% of the potential [but lower percentage of sales], depending on how the collection efficiency is calculated. Collection rates at or slightly below this level were also reported for the (large) municipality of Göteborg in Sweden (based on Hansen and Hansen, 2003).
Norway	In Norway there is a legal requirement to store mercury from zinc-production (one site). Mercury from zinc-production is a by-product and is regarded as waste for final disposal. The mercury-residue from zinc production is cemented in a sarcophagus and placed in a bedrock chamber at the production site. In order to clarify the Norwegian point of view we would like to state that we primarily want mercury out of circulation. Mercury is not recycled in Norway. Norway advocates less recycling of mercury from waste in the EU.
	The mercury waste from industry is mercury as a by-product from production of zinc. The mercury content of the waste is 30-40%. Approximately 56 tonnes of zinc residues were disposed in 2004, i.e., 17-

[3] Bayerisches Landesamt für Umweltschutz (Hrsg.): Zusammensetzung und Schadstoffgehalt von Siedlungsabfällen. 2003

Country	Comments submitted
	22 t Hg.
	On average Norway exports annually approximately 10 tonnes mercury-containing waste per year. This is mainly waste from products.
Portugal	In 2005 there is one company (AMBICARE INDUSTRIAL – Tratamento de Resíduos, S.A.) authorized to treat fluorescent tubes and other mercury-containing wastes (such as dental amalgams, batteries, thermometers, sfignomanometers and other mercury-containing equipment). The treatment process includes crushing, mechanical separation and distillation operations. The recovered mercury is considered a product of the treatment process and sold with a purity degree of approximately 98%.
	Portugal produces about 150 t of Hg wastes/yr (2002), and typically exports 40-50 t Hg wastes to Belgium, Germany, Spain and Switzerland for recovery
	Portugal appears to be collecting and recycling 150-200 t of batteries/yr.
Romania	200 kg Hg used in mining, of which 80% recycled.
	460 kg Hg recycled by the chlorine industry.
Spain	There exist no data about recycling, which is applied mainly to batteries and fluorescents. The process is expensive and cannot compete with illegal landfill.
	The national association of batteries estimates a total annual use of 27 tonnes of mercury-containing batteries (mercuric oxide?), and some 8 tonnes are selectively separated, while it's supposed that the rest ends in a landfill. In the community of Catalonia in 2004 some 4,2 tonnes of mercury-containing batteries (mercuric oxide?) were used, and 1,3 tonnes were collected and treated by mercury extraction.
	Similar to the mercury-containing batteries, lamps are collected separately, to be treated in such a way that the mercury is retained. In Catalonia some 150 to 190 tonnes/year of fluorescents are treated.
Sweden	There is no recycling of mercury in Sweden except for within the chlor-alkali industry. Mercury-containing waste such as thermometers, light sources, measuring equipments and electrical components are however reprocessed to separate the mercury fraction from the rest of the waste. The mercury fraction is then stored, awaiting final storage or stabilized and landfilled if the concentration of mercury is low. There are separate waste collection systems and already existing efforts for the collection of batteries, fluorescent lamps, amalgam waste etc.
	Boliden Mineral AB is currently storing about 8,000 tonnes of waste with a mercury content over one per cent, which represents approximately 330 tonnes of mercury. The waste is in intermediate storage. A further 400 tonnes of waste is generated each year, containing just over 20 tonnes/yr of mercury. The quantities involved for the two chlor-alkali industries Eka Chemicals AB and Hydro Polymers AB is estimated to be about 200 tonnes for each company. SAKAB's store of mercury waste is currently 2,000 tonnes, of which approximately 1,000 tonnes contain mercury levels over 1%. In many cases the quantity of mercury in the waste is not known, although SAKAB estimates that its store represents 80 tonnes of mercury. In addition to this, SAKAB also stores 1,800 tonnes of batteries, containing some 30 tonnes of mercury. An additional 50 – 100 tonnes of various mercury wastes arrives each year. The amount of mercury in the additional waste cannot be specified.
	During 2003 The Swedish EPA has approved application to export mercury waste of 256 tonnes including 226 tonnes discarded fluorescent tubes (0.005-0.015 % Hg, according to Netherlands), 10 tonnes fluorescent tube powder (0.05-0.3 % Hg, according to Netherlands) and 7 tonnes dental amalgam, i.e., 23 + 20 + 3000 kg = about 3-3.5 tonnes Hg in all of the above.
UK	UK generates about 100 million used lamps per year. In 2004, about 16 million were recycled. It is expected that around 20 million lamps will be processed in 2005. 200 t mercury lamps exported to Belgium and Germany in 2003 for recovery. 96 t mercury lamps exported to Belgium and Germany in 2004 for recovery. In Scotland, there are at least two waste treatment businesses that recover mercury from fluorescent light tubes (metallic mercury).

Country	Comments submitted
	At present, practically all chlor-alkali mercury contaminated waste in the UK arises from two sites. Generally, these generate 60 to 70 tonnes of waste per annum, with very high mercury content.
	No tonnage figures available [for Hg in natural gas cleaning wastes], but it is understood that this material is normally sent to a processor in mainland Europe for treatment.
	18 t lab reagents exported to Germany in 2003 for Hg recovery. 20 t lab reagents exported to Germany in 2004.
	A report to the then Department of the Environment in 1996 (consultants ERM) estimated that approximately 1 tonne of mercury per annum was released in the UK waste stream from clinical thermometers, extrapolating from the use in one Health Authority. However, it is understood that use of mercury-in-glass thermometers in the Health Service has continued to declined since this report.
	In 2002, dental waste estimated at 6.3 t, of which approximately 3 t sent for disposal/recycling. One UK Company processes about 1.5 tonnes of dental amalgam per annum. A second Company process some, but figures are not available.
EU	For mercury in all measuring and control equipment in the European Union, Floyd *et al.* (2002) estimate that 15% is collected for recovery, 80% is disposed of to solid waste and 5% break during use. The average European household uses 21 batteries a year, according to EU figures.

Despite a wide range of useful information, it is necessary to keep in mind that it has not been possible to receive detailed information from all recyclers – or even to identify all of them – within the scope of this project. Nevertheless, from this body of information, responses to questionnaires and direct contacts with recyclers, a number of basic observations may be made about this sector.

Collection
Different Member States have very different incentives, government priorities, budget constraints and political pressures that may influence national activities in the area of mercury recycling. This translates to a range of very different collection programmes, and a great variation in collection rates across the EU. In most countries the quantities of mercury waste generated are not well known, and the mercury content of various wastes, rates of recycling, disposal pathways and mass flows are no better known.

Transfers
As indicated above, there are numerous transfers of mercury wastes across EU internal and external borders to recycling or disposal specialists. There is also ample evidence of waste transfers that are not properly marked or recorded (Legambiente 2005). And further complicating a fuller understanding of mercury metal and waste transfers, there is the occasional use of entrepot or “bonded” warehouses. By using an entrepot warehouse, a company based in the EU is not obliged to report goods received at the warehouse as having entered the EU. For example, an EU company could bring by-product mercury from a South American mining operation to an entrepot warehouse in Antwerp, where it would not be recorded as an EU import until such times and in such quantities as the mercury may be taken out of the entrepot warehouse and formally delivered to an EU recycler for cleaning before resale.

These sorts of complexities make it extremely difficult to obtain a good understanding of EU waste transfers and mercury content in spite of the best intentions and record-keeping of the authorities.

Treatment
While the main methods for treating mercury wastes are relatively few, as described above, the waste treatment services offered by recyclers show great diversity. Some mercury waste merely

needs to be filtered and cleaned, with no thermal treatment at all, such as the mercury removed from chlor-alkali cells or produced at industrial mining sites.

Other types of waste, such as wastewater treatment sludges or filter cake, may be recycled by some industries and disposed of by others, depending on the special circumstances, local regulations, the timing, knowledge of options and costs, etc.; although it should be added that as in many areas of business, the level of trust or reliability between waste producers and waste recyclers may be more important than the relative cost of different options for waste treatment.

For a variety of reasons, often related to an original area of expertise or local economic incentives, a mercury waste recycler may treat only batteries, another may treat only lamps, while others offer a much more diverse range of services. Furthermore, even those who treat only lamps may send the fluorescent powder to a different recycler to be treated, just as one who removes the mercury from silver oxide batteries may send the silver residue elsewhere to be further refined.

Manufacturers of mercury-containing equipment also serves as recyclers of mercury. German manufacturers of thermometers obtain all the mercury from recycling mercury-containing waste products.

For such reasons it is also difficult to characterise or model the mercury recycling business in the EU.

Marketing of mercury
A final area of complexity involves the final disposition of mercury recovered from a recycling process. Some recyclers have an arrangement with the waste provider (common in the chlor-alkali industry, for example) whereby the provider retains ownership of all mercury in the waste, and the mercury is returned to the waste provider after recovery. Some recyclers sell the recovered mercury to one or more metals brokers, while still others take responsibility for marketing the mercury themselves.

Recycling rate
The recovery of mercury through the recycling of different wastes is summarised in Table 4-9, which shows the total mercury contained in product-related wastes, the average recycling rate, and the total mercury recovered from each product group. The following Table 4-8 lists the types of wastes treated and the quantity of mercury recovered by the majority of the EU recyclers.

Table 4-8 EU recyclers of mercury wastes

Country	Name of facility, town	Types of waste supplied	Treatment method	Year	Mercury recovered 2007 (tonnes)	
					minimum	maximum
AT	Fernwärme Wien	Batteries			<0.5	1
AT	Rumpold	Batteries			<0.5	1
BE	Indaver Relight BV	TL-lamps, button batteries (AgO), thermometers, industrial waste containing mercury	distillation (490 kg Hg)	2005-2007	0.4	0.6
BE	Erachem-Comilog	Batteries			<0.2	0.8
BE	Xstrata	Batteries			<0.2	0.8
BE	Revatech	Batteries			<0.2	0.8
BE	Umicore	Batteries			<0.5	2
BG						
CH	Batrec Industrie AG - CH-3752 Wimmis - Switzerland	Batteries (AlMn, AnC, ZnO, Li, LiMn, Li-ion), Hg-containing catalysts, dental amalgams, thermometers, HID lamps, laboratory reagents, activated carbon, other Hg-containing wastes	Pre-treatment and distillation. Hg recovered has a purity of 99,995 – 99,9995 (12-13 tonnes Hg 2005) (8-9 tonnes 2007)		8	9
CZ	Bome s.r.o.	Amalgams			<0.5	1
DE	Accurec	Batteries			<0.5	1
DE	GMR Gesellschaft für Metallrecycling mbH - Leipzig	All types of waste	No information	No information	4	8
DE	Remondis NQR - Lübeck	Batteries, button cells	Thermal vacuum destillation (3 tonnes Hg)	2006	2.5	3.5
DE	Redux	Batteries			<0.5	2
ES	Pilagest	Batteries			<0.5	2
ES	Technicas Reunidas	Batteries			<0.5	2
FI	Oy Lindström Consulting Ab	Amalgam	No domestic recovery- collected waste is exported		n.a.	n.a.
FR	Citron	Batteries - AlMn, ZnC, ZnO			<0.5	2
FR	Duclos Environnement	Batteries			<0.2	0.8
FR	EuroDieuze Industrie	Batteries			<0.2	0.8
FR	MBM	Batteries			<0.2	0.8
FR	Recupyl	Batteries - AlMn, ZnC, ZnO, Li, LiMn, Li-ion			<0.5	2
FR	SNAM	Batteries - NiCd, NiMH			0	0

Country	Name of facility, town	Types of waste supplied	Treatment method	Year	Mercury recovered 2007 (tonnes)	
					minimum	maximum
FR	Valdi	Batteries - AlMn, ZnC, ZnO			<0.5	1
FR	Acoor Environnement	Batteries			<0.2	0.8
GR	Polyeco	Batteries			<0.2	0.8
IE	KMK Metals Recycling	Batteries			<0.5	1
IT	Veneta Plastica	Batteries			<0.5	1
LV	Lamp demercurization centre	Hp lamp waste	distillation (191.93 kg Hg)	2006	0.15	0.25
NL	Claushuis Metaalmaatschappij B.V.	Especially mercury recovered from gold mines, that merely needs cleaning; batteries, thermometers, switches, dental amalgam and capsules, capacitors, containers contaminated with mercury, activated carbon, fluorescent powder	various		200	210
NL	BMT Begemann Milieutechniek BV - Dordrecht	Batteries, catalysts, activated carbon, sludges, soils, fluorescent powder			10	15
NL	Van Peperzeel	Batteries	vacuum distillation, gravity separation		<0.5	2
NO	RENAS	Mercury treatment for storage			n.a.	n.a.
SI	(no facilities)					
SK	Electro Recycling, s.r.o. - Slovenská Ľupča	lamps, thermometers	R4,R5 (no Hg recovered in 2006)	2006	<0.1	0.1
SK	ENZO-VERONIKA-VES a.s. - Dežerice	lamps	R4,R5-17.024 t Hg (probably kg)	2006	<0.1	0.1
SK	DETOX s.r.o. - Banská Bystrica	lamps	R4, R5-47.923 t Hg (probably kg)	2006	<0.1	0.1
SK	FECUPRAL spol. s r.o. - Prešov	lamps	R4, R5	2006	<0.1	0.1
SK	Argus, s.r.o. - Lok	Lamps, thermometers	R4, R5-87.874 t Hg (probably kg)	2006	<0.1	0.1
SE	Saft Batteries	Batteries			n.a.	n.a.
SE	SAKAB	Mercury treatment for storage			n.a.	n.a.
UK	G & P Batteries	Batteries – mechanical process			0.1	0.2
UK	Mercury Recycling Ltd.	Lamps,batteries, etc.			<0.5	2
UK	Quicksilver Recovery Services Ltd.	Lamps,batteries, etc.			<0.5	2
TOTAL					230	280

Sources: Questionnaires, company websites, EBRA, consultant estimates

While the mercury production of all EU recyclers is clearly not precisely known, and some of the mercury waste (and especially mercury from large gold mining operations) originates outside the EU, it is estimated from the above table that the EU generated some 230-270 tonnes of mercury from recycling in 2007.

The total of Table 4-7 exceeds the recycling total of 112 tonnes presented in Table 4-9 because Table 4-7 includes by-product mercury from smelting and gas cleaning wastes, and also mercury recovered from mercury wastes originating outside the EU, including mercury that may need only a simple cleaning treatment. On the contrary, the table above does not include mercury that may be recovered on-site at chlor-alkali facilities, so these two tables really cannot be easily compared.

4.2.4 Future trends

The supply of mercury became more volatile in recent years as primary mercury mines have closed down. Subsequently, the supply became less volatile as more recyclers have come on line, as waste disposal prices rise while waste disposal options decrease, as tightened regulations and awareness send more wastes to recyclers, etc. The quantities of mercury available in the waste stream and present low rates of recycling for many wastes suggest that present supplies of recycled mercury could be two times higher even without the contributions of by-product mercury from gas cleaning and smelting operations.

Export ban/safe storage
The coming EU export ban and storage obligations will be a great opportunity for EU recyclers. As other EU inventories are depleted, recycling will become one of the key sources of EU mercury. Overall, the recycling business will be very little affected by the export ban for several reasons:

1. recycling is done primarily as an alternative to disposal, and not for the main purpose of selling mercury;

2. EU recyclers still produce less mercury than the EU market requires; and

3. EU recyclers typically do not export much mercury themselves, except perhaps small quantities of highly refined Hg for pharmaceutical or similar uses.

4.3 Community wide possibilities for the future as regards handling of mercury-containing waste in products

As illustrated in Chapter 4, and to a lesser extend Chapter 2 of this report, various legislation and waste management schemes are in effect in the EU Member States with the aim of preventing mercury containing waste from giving rise to mercury releases to the environment during manufacturing, usage and disposal/recycling of products. As also documented in this report, the overall efficiency of these systems is however far from covering the most of the mercury being disposed of in the European Community. The overall recycling of mercury in the EU27+2 is estimated at some 25% of the mercury amount disposed annually. More mercury containing waste is actually collected in dedicated waste management practices, because some of this waste is not recycled, but disposed of on specialised hazardous waste landfills or normal landfills. Yet collection efficiencies above 50 % are very rare (also for other toxics than mercury), and generally only occur in countries which have made comparatively high investments and efforts to promote collection. This also indicates, that even with substantial efforts promoting increased mercury waste collection, it should not be expected that much more than about half of the mercury introduced into society will be collected and treated safely. Some of the remaining mercury is disposed off with municipal waste; that is, incinerated or landfilled; and the rest is lost as diffuse releases to the environment.

As long as introducing mercury on the market is still accepted, and mercury is still circulating in significant amounts in society, the only way to reduce the releases of mercury waste to the environment is to perform activities that will further enhance collection and safe treatment. Such activities could include the ones listed below, among others. Note that substantial experience has been gained with these types of activities in some Member States, only a wider use, more emphasis, and transfer of best practices, is needed:

- Increase the awareness and technical insight of mercury's presence in waste (generally, and for specific products), and the need for its safe collection and treatment, through effective communication, at all levels: Producers, users/consumers, waste collectors/handlers/treaters, and local, national and regional authorities.
- Improve physical collection/sorting schemes and methods. For example for dental amalgam, button cell batteries, and sorting of electric/electronic components.
- Increase enforcement, reporting requirements and control of all steps in mercury waste collection, handling and treatment.
- Introduce a wider use of producer/importer life cycle responsibility with well defined obligations and goals, in line with what is already in force with the WEEE Directive for certain mercury-containing waste types. This will ensure that costs for the needed collection and treatments efforts are covered by the entities putting these products on the market, and will promote the marketing of mercury-free alternatives.
- Establish a task force dedicated to the community wide promotion of increased collection and recycling/safe disposal of mercury containing waste along the lines stipulated above. The task force could include Community agencies, Member States authorities, representatives of waste collection companies and mercury waste recyclers, producers of mercury containing products and materials, and perhaps other major stakeholders. From the beginning, the task force should have a well defined mandate and goals, and a budget for 3-5 years of dedicated work. If similar relevant initiatives exist for other hazardous waste types, a mercury task force should cooperate with these, or if relevant, existing initiatives could have mercury included/emphasised in their mandate.

Once collected, the further fate of mercury waste must be re-considered periodically according to the development of the supply/demand situation in future years. Should mercury waste be retired permanently, as planned in Sweden, be stored safely in long-term storage facilities, or be recycled and re-marketed within the EU (the proposed export ban would prevent export of some forms of mercury)? As mentioned above, the proposed directive on export ban and safe storage will have significant influence on these issues.

4.4 Summary of waste management and recycling

Sources of mercury-containing waste
An overview of quantities ending up in waste is presented in Table 4-9 based on the information provided in Chapter 2. The major sources of mercury in waste from intentional mercury use, and also the major sources of recovered mercury, are waste from chlor-alkali production and dental amalgam. It should be noted that the recycling efficiencies are quite uncertain for measuring equipment and miscellaneous uses. The lowest mercury recycling efficiencies are found for light sources, batteries and chemicals. All are characterised by a waste stream with a rela-

tively low mercury concentration. For chemicals, the low collection efficiency in particular is due to the fact that no specific collection of wastes takes place for mercury-containing PU and paints, the major application areas for the chemicals. Note that recycling efficiency is generally lower than collection efficiency because some collected mercury containing waste may be landfilled/deposited and not recycled.

Table 4-9 Mercury in waste from intentional uses of mercury in 2007, best estimate

Products category	Quantities ending up in waste Tonnes Hg/year	Quantities recycled Tonnes Hg/year	Contribution to total amount recycled, %	Recycling efficiency within category and totally, %
Chlor-alkali production	119	35	34	29
Light sources	14	1.6	2	11
Batteries	30	4	4	13
Dental amalgams	95	30	29	32
Measuring equipment	21	4.5	4	21
Switches, relays, etc.	14	7	7	50
Chemicals	41	6.5	6	16
Miscellaneous uses	70	13	13	19
Total (rounded)	404	102	100	25

Legislation

Most waste fractions of mercury-containing products are considered hazardous waste regardless of the mercury content. Some waste types are covered by specific legislation and are only considered hazardous waste if certain concentration thresholds are exceeded. Specific regulation on the collection of mercury-containing products apply to mercury-containing lamps (WEEE Directive), batteries (Battery Directive), switches and lamps in vehicles (ELV Directive), and switches, relays and other mercury-containing components in electrical and electronic equipment (WEEE Directive). For each of the waste fractions there is a specific entry in the European Waste Catalogue, and in principle it should be possible to obtain an overview of the waste management situation across the EU for these waste categories. Member States are obliged to keep registers of the waste generated and the disposal method, but data on the individual waste entries are not generally available at community level, and the results of this study indicate that knowledge or concern about these wastes may generally be limited.

Collection and recycling

Different Member States have very different incentives, government priorities, budget constraints and political pressures that may influence national activities in the area of mercury recycling. This translates to a range of very different collection programmes, and a great variation in collection rates across the EU. In most countries the quantities of mercury waste generated are not well known, and the mercury content of various wastes, rates of recycling, disposal pathways and mass flows are no better known.

As shown above, the overall recycling of mercury in the EU27+2 is estimated at some 25% of the mercury amount disposed annually. More mercury containing waste is actually collected in dedicated waste management practices, because some of this waste is not recycled, but disposed of on specialised hazardous waste landfills or normal municipal landfills. Yet collection efficiencies above 50% is very rare, and generally only occurs in countries which have made comparatively high investments and efforts to promote collection. This also indicates, that even with substantial efforts, it should not be expected that much more than half of the mercury introduced into society with products with many and diverse users can be collected and treated safely. Some of the remaining mercury is disposed off with municipal waste, that is, incinerated or landfilled, and the rest is lost as diffuse releases to the environment.

There are numerous transfers of mercury wastes across EU internal and external borders to recycling or disposal specialists.

Treatment

While the main methods for treating mercury wastes are relatively few, the waste treatment services offered by recyclers show great diversity. Some mercury waste merely needs to be filtered and cleaned, with no thermal treatment at all, such as the mercury removed from chlor-alkali cells or produced at industrial mining sites. Other types of waste are treated by thermal processes to make the mercury evaporate for succeeding condensation, by hydrometallurgical (wet) extraction processes; some of which involve electrolytic extraction. Mercury wastes may be recycled by some industries and disposed of by others, depending on the special circumstances, local regulations, the timing, knowledge of options and costs, etc.

For a variety of reasons, often related to an original area of expertise or local economic incentives, one mercury waste recycler may treat only batteries; another may treat only lamps, while others offer a much more diverse range of services. Manufacturers of mercury-containing equipment also serve as recyclers of mercury in some cases.

Trends

The coming EU export ban and storage obligations will be a great opportunity for EU recyclers. As other EU inventories are depleted, recycling may become one of the key sources of EU mercury. The recycling business is not expected to be negatively affected by the export ban or storage obligations in the near future.

In the past, consumption of mercury in the EU has been declining significantly. The decline is expected to continue, especially due to the ongoing conversions of mercury cell chlor-alkali production facilities. Yet, mercury consumption for other purposes may decline at a more moderate rate than previously, unless restricted further. In the hypothetical or future case of a near complete ban of sale of mercury for intentional use, the need for special waste management for mercury products would continue for a decade or two as the stock of mercury in circulation would be retired permanently. Thereafter the need would be limited to relatively few companies'/activities' need for management of mercury-containing residues from unintended mercury mobilisation from mining, gas cleaning, etc. This would be a rather different situation to the present, with few easily controllable stakeholders involved, and deposition/storage of residues rather than recycling of mercury.

Options for release reductions

As long as introducing mercury on the market is still accepted, and mercury is still circulating in significant amounts in society, the only way to reduce the releases of mercury from waste to the environment is to perform activities that will further enhance collection and safe treatment. Some specific recommendations are given above. Note that substantial experience has been gained with such activities in some Member States; what is needed is a wider use of them, more emphasis, more cooperation and exchange of best practices. This could be promoted by further political prioritisation, and by establishment of a task force with this focus and including the major stakeholders across Member States.

5 National legislation on mercury exceeding EU legislation

5.1 Restrictions on mercury in products

National restrictions on mercury in products going beyond EU legislation as informed by the countries' questionnaires and stakeholder consultation responses are summarised in Table 5-1 below. It cannot be ruled out that a few other Member States may have restrictions on some specific uses of mercury.

The world's most progressive legislation on mercury in products entered into force 1 January 2008 in Norway with a general prohibition on production, import, export, sale and use of mercury and mercury compounds. The regulation provides for a few general exemptions until 31 December 2010.

Of the EU Member States, Denmark and the Netherlands have a general prohibition on import, export and sale of mercury and mercury-containing products, but a wide range of products containing mercury are exempted.

Sweden has a prohibition on production, sale and export of thermometers and other measuring equipment, level switches, pressure switches, thermostats, relays, circuit breakers and electrical contacts, but also permits a few exemptions. Sweden intends to enact a general ban in the relatively near future.

Table 5-1 National restriction on mercury in products going beyond EU legislation

Scope of legislation	Country	General exemptions	Name of instrument
General prohibition on production, import, export, sale and use of mercury and mercury compounds in concentrations above 0.001 percent by weight. (=10 mg/kg) The prohibition do not apply to products regulated by EC Directives on packaging, batteries, components in vehicles and electrical and electronic equipment The prohibitions do not apply to mercury that occurs naturally in coal, ore and ore concentrate	NO	Until 31 December 2010 for substances and preparations: - thiomersal in vaccines - Amalgam for dental treatment of patients who must be treated under general anaesthesia or who are allergic to ingredients in other dental fillings - Contact material in welding equipment Until 31 December 2010 for articles: - Polarographs	Amendment of regulations of 1 June 2004 no 922 relating to restrictions on the use of chemicals and other products hazardous to health and the environment (Product regulations). Entered into force 1 January 2008

Scope of legislation	Coun-try	General exemptions	Name of instrument
General prohibition on import, export and sale of mercury and mercury-containing products in concentrations above 100 mg/kg in their homogeneous components The prohibition do not apply to: - natural impurities in coal - used products which fulfilled Danish requirements at the time they were first offered for sale - products regulated by other legislation, unless they are stated in the Annex.	DK	Mercury-containing products for which import, sale and export are permitted: 1. Dental products for filling permanent molar teeth, where the filling is worn 2. Mercury-wetted film switches and relays which meet EN 119000, for specified applications in businesses: - data and telecommunication - process control - PLC remote control of energy supply - electrical test systems 3. Thermometers for special applications: - calibration of other thermometers - analysis equipment 4. Special light sources: - discharge lamps, including energy-saving bulbs - for analysis operations - for graphic operations 5. Flash units for safety installations on railway lines 6. Manometers for calibration of other pressure gauges 7. Barometers for calibration of other barometers 8. Electrodes for special applications: - polarographic analysis - potentiometric analysis - calomel reference 9. Mercury-containing chemicals for special applications: - raw materials for analysis reagents - analysis reagents - standards - preservation of starch for laboratory use - isotope dilution testing - catalysts 10. Products for research, including odontological research 11. Products for teaching 12. Products for vital applications in aircraft 13. Products for the repair of existing mercury-containing equipment	Statutory Order no 627 of 01.07.2003 on prohibition of import, sale and export of mercury and mercury-containing products

Scope of legislation	Coun-try	General exemptions	Name of instrument
General prohibition of manufacture and import of products (effective as of 1 Jan 2000)	NL	a heating thermostat as well as a mercury switch which is exclusively meant for use in a heating thermostat; and b. an activity meter for animals, as well as a mercury switch which is exclusively meant for use in an activity meter for animals. 2. until 1 January 2005, a barometer containing mercury;	Bulletin of Acts and Decrees of the Kingdom of the Netherlands No. 553: Decree of 9 September 1998, comprising regulations regarding products containing mercury
General prohibition of possessing or use for trading or production if the product has been taken into use for the first time after 1 January 2003 (1 January 2006 for barometers)	NL	a. a pycnometer or porosimeter for measuring the air space volume of soil or other porous solids; b. sampling equipment designed to measure particles in liquids; c. a calibration instrument meant for low flow-rate flow meters; d. a cuvette, meant for determining the chemical oxygen demand; e. a McLeod compression manometer, meant for measuring absolute pressures lower than 20 kPa; f. a submersible pump; g. a roll-spot welding head, meant for seam welding; h. a slip ring; i. a semiconductor test system, as well as a mercury relay of which the maximum mercury content per component does not exceed 0.15 gram and which is exclusively meant for use in semiconductor test systems; j. a mercury thermometer exclusively intended to perform specific analytical tests according to established standards; k. equipment for the calibration of platinum resistance thermometers using the triple point of mercury; l. a gas discharge lamp, with the exception of: 1.a fluorescent lamp for purposes of lighting with an integrated means of starting when it contains more than 10 mg of mercury; 2. a non-circular fluorescent lamp for purposes of lighting with a single lamp-cap terminal connection when it contains more than 10 mg of mercury; 3. a straight fluorescent lamp for purposes of lighting with two lamp-cap terminal connections when it contains more than 20 mg of mercury; m. a product for use in shipping in which	Bulletin of Acts and Decrees of the Kingdom of the Netherlands No. 553: Decree of 9 September 1998, comprising regulations regarding products containing mercury

Scope of legislation	Coun-try	General exemptions	Name of instrument
		the use of mercury is prescribed by or under law, equipment directly related to shipping in which the use of mercury is deemed to be necessary by the Minister of Transport and Public Works and ships' equipment to which Directive no. 96/98/EC of the Council of the European Union of 20 December 1996 on marine equipment (OJEC 1997 L 46) applies; n. a product for use in aviation for which the use of mercury is prescribed by or under the Aviation Act, and equally any product directly related to aviation purposes in which the use of mercury is deemed to be essential by the Minister of Transport and Public Works; o. equipment in use by the Armed Forces, in which the use of mercury is prescribed by or under law, or equipment necessary to the operational responsibilities of the Armed Forces in which the use of mercury is deemed to be essential by the Minister of Defence; p. a photographic film, a photographic plate and photographic paper, in as far as the film, plate or paper do not contain more than 0.3 mg of mercury per kg of product. Electrotechnical components which serve as spare parts for equipment used for the first time before 1 January 2003	
General prohibition of commercial export of mercury and chemical compounds and preparations containing mercury	SE		Ordinance (1998:944) Concerning Prohibitions etc in Certain Cases in Connection with the Handling, Import and Export of Chemical Products
Prohibition of production, sale and export **of the following goods** if they contain mercury: 1. clinical thermometers; 2. other thermometers; 3. level switches, pressure switches, thermostats, relays, circuit breakers and electrical contacts; 4. measuring instruments other than as set forth in 1-3 above. The goods may not be commercially imported from countries which are not members of the European Union. The goods may only be used if they were in use in Sweden prior to 1 January 1995	SE	The Swedish Chemicals Inspectorate may issue regulations regarding exceptions. Current exemptions include (the list may not be exhaustive): - porosimeters - strain gauges plethysmographic devices for specific application	Ordinance (1998:944) Concerning Prohibitions etc in Certain Cases in Connection with the Handling, Import and Export of Chemical Products - see information on planned regulation below

5.1.1 Legislation in preparation

In February 2006, the Swedish Government notified a proposal for a general, national ban on mercury to the European Commission and the World Trade Organization (WTO) (Kemi 2008). In December 2007, the Swedish Government informed the European Commission of its intention to enforce the ban within short. However, the entry into force has been somewhat delayed and the decision has not yet been taken. The present ban on mercury in certain products would be extended to a general ban, including the marketing of mercury-containing products and the use of mercury, for example as dental amalgam and analytical chemicals. According to the present text, it would not be allowed to export mercury and mercury-containing products. Exemptions are proposed for applications covered by harmonised EC legislation, for example button cell batteries and fluorescent lamps, and for certain other applications to provide time for development and transition to alternatives.

5.2 Mercury waste management legislation

This section presents a brief overview of national legislation pertaining to waste from mercury in products, to the extent that national legislation surpasses Community legislation in this area..

As reported on the Member States' questionnaires and stakeholder consultation responses, national restrictions on mercury wastes exceeding EU legislation are summarised in Table 5-2 below. Specific exemptions and other details of these Member State measures were not always provided in the submissions. Moreover, it cannot be ruled out that a small number of other Member States may have a few more restrictions that were not submitted during these consultations, but it is apparent that this table captures the vast majority of such measures.

Considering the diversity of population density, land area, culture, etc., it is evident that Member States have focused on different aspects of mercury waste for their own technical and political reasons. However, landfilling and incineration are the two main areas where many Member States have legislation beyond the current EU legislation.

In general, Sweden is recognised to have the most far-reaching approach to mercury waste management, banning the export and requiring temporary storage of all wastes containing more than 0.1% mercury until such time as appropriate permanent bedrock disposal is available, but no later than 2015.

Table 5-2 National mercury waste requirements going beyond EU legislation

Country	Brief description or scope of legislation or other requirements
Austria	The Abfallbehandlungspflichtenverordnung (BGBl. II Nr. 459/2004 idF BGBl. II Nr. 363/2006), among other stipulations, states specifically how mercury lamps, mercury-containing equipment and amalgam residues are to be treated.
	According to Altölverordnung 2002 (BGBl. II Nr. 389/2002), engine oils may not contain mercury.
	The Kompostverordnung (BGBl. II Nr. 292/2001) limits the mercury contents of material for compost production to 5 mg/kg dry matter.
	Restriction on landfilling of waste containing mercury: Austria has no underground waste disposal. There are different landfills in Austria (for excavated soil, for construction and demolition waste, for residual waste, for mass waste), the mercury limit value there is given between 1 – 20 mg/kg TS. (Exception: mercury as sulphide: 3000 mg/kg TS - provided the waste is solidified). Any other mercury-containing waste has to be de-contaminated or land filled in an underground storage.
	Restriction on incineration of waste containing mercury: In waste incineration plants mercury emissions are limited according to the Austrian waste incineration ordinance to 0,05 mg/m^3 (half-hour mean value and daily mean value, dry, 11% or 3% O_2). This value applies also to plants where waste is co-incinerated, to cement plants and combustion plants.
	Mercury-containing appliances (thermometers, electrical equipment, batteries, fluorescent tubes, etc.) are defined as hazardous wastes, requiring separate collection with a notification form. For such wastes arising from households there is a special charge-free collection system ("Problemstoffsammlung") provided by the municipalities.
	For dentists an amalgam recovery system is mandatory. The amalgam is recycled in Austria (recovery of Ag and Hg) by a specialised company.
Belgium (Flanders)	In Flanders there is a landfill ban on wastes containing toxic substances. The decision of the Flemish government of June 1st 1995 concerning general and sectoral provisions with regard to environmental hygiene contains the following provisions. The following wastes may not be accepted at a landfill site: • Wastes containing more than 0.1% toxic organic substances, characterised by the symbol T+ or T, with reference to dry waste. • Wastes containing toxic inorganic substances in concentrations exceeding the thresholds for classifying preparations of these substances as T+ or T on the basis of the toxicological properties of the substances (R-sentences 23, 24, 25, 26, 27, 28, 39, and 48) (Directive 88/379/EEG of June 7th 1988 as modified), with reference to dry waste. Summarized, this means that waste containing more than 0.5% of organic mercury compounds or 0.5% of inorganic mercury compounds (except Hg-Sulphide), may not be landfilled in Flanders. In practice a threshold of 100 mg/kg is applied since this was the limit for toxic waste in Belgium.
	Flemish legislation doesn't contain restrictions on the input of mercury to waste incineration installations. All environmental conditions are being enforced by imposing strict emission limits. The European Directive on the incineration of waste excludes the incineration of wood waste with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood-preservatives or coating, and which includes in particular such wood waste originating from construction and demolition waste. Flemish legislation, however also imposes emission limits for mercury when 'non-contaminated treated wood waste' is (co-)incinerated. 'Non-contaminated treated wood waste' is defined as treated wood waste with the exception of wood waste which may contain halogenated organic compounds, PAHs or heavy metals as a result of treatment with wood-preservatives or coating, and which includes in particular such wood waste originating from construction and demolition waste. For installations < 5 MW there is no emission limit for mercury. For installations between 5 and 50 MW the emission limit for mercury is 0.1 mg/Nm^3. For installations > 50 MW the emission limit for mercury is 0.05 mg/Nm^3.

Country	Brief description or scope of legislation or other requirements
	For the incineration of other wastes the emission limits for mercury are the same as the limits from the Waste Incineration Directive.
	Landfilling of mercury is prohibited in Flanders for the reasons quoted under the restrictions for landfilling of waste containing mercury. This prohibition goes further than the European directive on landfills.
	Chapter 5.58 of the decision of the Flemish government of June 1st 1995 concerning general and sectoral provisions with regard to environmental hygiene contains the environmental conditions for crematoria. Summarized, this means that emission limits for dust, mercury (compounds), SO_2, NOx and dioxins are imposed. The emission limit for mercury and mercury compounds (expressed as mercury) is 0.2 mg/Nm^3.
	Chapter 5.43 of the decision of the Flemish government of June 1st 1995 concerning general and sectoral provisions with regard to environmental hygiene contains the environmental conditions for discharges to water for dentists. Summarized, this means that a certified amalgam separator must be installed. The emission limit for total mercury in the discharged water is 0.3 mg/l. Furthermore these provisions contain technical specifications of the amalgam separator and require that the mercury-containing waste removed from the amalgam separator must be handed over to an authorised or registered transporter of waste.
Finland	Disposal requirements for landfill deposition of mercury waste: • Waste with <40 ppm mercury can be deposited in industrial waste deposit area. • Waste with >40 ppm mercury must be deposited in special/hazardous waste deposit area. With special permission, certain types of waste with mercury content are admissible for deposition in hazardous waste landfills.
	All mercury-containing wastes are neutralised or treated in a well-controlled sulphidation reactor before deposition in special landfills to minimise emissions. There are supplementary requirements for solubility of mercury from wastes in landfills.
France	The regulation on rejections restricts the amount of mercury waste going into the incinerating process.
	Stabilization using hydraulic binders is required on the leachable fraction for storage in Technical Landfilling Center (TLC), in respect of regulation limits.
	Solidification is required for storage in a salt mine.
Norway	There is one zinc production site in Norway. The mercury residue is considered as waste. The residue is cemented in a sarcophagus and placed in bedrock at the production site. There are no emissions of mercury reported from this activity.
Netherlands	Landfilling of measuring and control equipment containing mercury (e.g. thermometers) and separately collected batteries are not allowed under Dutch legislation. Landfilling of other mercury-containing wastes and "by-products" are not allowed in the Netherlands by legislation, and export to deep underground storage is only allowed if one has gone to all lengths to prevent the generation of mercury-containing waste, or to treat the waste.
	The national waste management plan sets standards for the method of treatment of wastes. For mercury-containing wastes the "lowest" standard is separating the mercury and recovering the other fractions like metals, glass etc. This "minimum standard" is used in permitting waste treatment installations.
	Mixing of mercury-containing wastes (> 10 ppm) with other wastes for preparation of a mix principally used as a fuel or other means to generate energy, is not allowed.
Sweden	Restrictions on landfilling of waste containing mercury: Sweden has from the 1st of August 2005 implemented an ordinance regarding mercury in waste (SFS 2001:1063), which states: Waste that contains at least 0,1 percent by weight mercury and is not in a permanent landfill shall be placed in terminal bedrock storage by 1st January 2015 at the latest. It is not allowed to dispose mercury waste before the 1st of January 2015 in a way that prevents terminal storage in bedrock. The Swedish EPA may, on a case-by-case basis, allow certain exemptions from the bedrock storage requirement.

Country	Brief description or scope of legislation or other requirements
	Restrictions on export of waste containing mercury: According to Ordinance (1998:944) Concerning Prohibitions etc. in Certain Cases in Connection with the Handling, Import and Export of Chemical Products, since 1997 it is forbidden to professionally export mercury and its compounds as well as preparations, if they contain mercury. Its purpose is primarily to prevent the export of mercury-containing waste, but in practice export of chemical products that contain mercury, e.g. amalgam and analytical chemicals, are also banned. The Swedish EPA may permit transport of waste containing mercury if the requirements in the EU regulation for shipment of waste are fulfilled. Since August 1st 2005 all waste containing more than 0,1% by weight mercury must be disposed of in permanent underground storage at the latest by the year 2015. It is furthermore forbidden to dispose of such waste in any other way. It will, however, from 2010, be possible for the Swedish Environmental Protection Agency to grant exemptions from this provision if there are exceptional reasons or if the amount of waste in question is so small that the disposal method is unreasonable. These provisions are found in the Waste Ordinance 2001:1063.
	Mercury waste that will be stored in bedrock (proposed regulation): The requirements for pre-treatment of mercury before terminal storage in bedrock are under investigation. The Swedish government has, under the recently approved legislation (which says that mercury over 0,1 percent should be stored underground), appointed a coordinator who is to work with the issue. In the assessments made prior to the recent legislation, it has generally been assumed that the mercury should be stabilised and stored as a mercury sulphide.
UK	In terms of exports of waste containing mercury, the Waste Shipments Regulation (WSR) bans the export of any waste for disposal from the EU (except to EFTA). The WSR also allows Member States to go further than this and ban exports of any waste for disposal from their territory. The UK has banned such movements. Therefore, if mercury-containing waste has to be disposed of (as opposed to recovered or recycled) then the UK ban on export would apply.
	In terms of the domestic hazardous waste controls, dental amalgam is classified as a hazardous waste (when discarded). As a result of the application of the Hazardous Waste Regulations to dentists, the UK expects more amalgam to be collected separately, and possibly more dentists will use alternatives to amalgam.

6 Policy options for reducing mercury inputs to society and for improved management of mercury

During this analysis of mercury use in products and applications in the EU, and the fate of mercury already circulating in society, a number of products were identified for which further regulation or other restrictions might have significant benefits for society and the environment.

In this regard, it is useful to recall that the general objective, or the overall goal, of any further policy measures is to protect human health and the environment from the release of mercury to the environment. Furthermore, the specific objective is to reduce the impacts on human health and the environment by: 1) reducing current mercury inputs to society, and 2) improving management of mercury already in circulation in society, both in the short and the long term.

Following a rough screening of operational objectives, general EU-level policy options,[6] national legislation already in place, other EU-level measures already under discussion, and extensive consultation with DG Environment and DG Enterprise, several key products were selected for further investigation of policy options. The selection of products for further investigation of policy options was generally based on four core criteria established by DG Environment:

- the quantity of mercury used in the product or product group in the EU;
- the availability of viable mercury-free alternatives;
- the political feasibility of implementing substantive policy measures; and
- the consistency of such policy measures with the Community Mercury Strategy.

6.1 Selected products and product groups

On the basis of the Phase I analysis of this study, and the further assessment according to the core criteria described above, the following products and product groups were selected – in no particular order of priority – for a more detailed review of the main impacts resulting from the implementation of possible further policy measures:

- Dental amalgam;
- Measuring devices (specifically thermometers, barometers and sphygmomanometers) for professional uses;
- Mercury catalysts for polyurethane elastomers;
- Mercury porosimetry.

In addition, some basic observations and straightforward policy recommendations will be made with regard to two other applications of mercury:

- mercury compounds used as biocides, e.g. in paints; and
- the use of mercury in lighthouses.

6.2 Impact assessment methodology

The more detailed assessment follows the principles of the European Commission's Impact Assessment Guidelines but does not have the scope of a full impact assessment. For each of the products or product groups, the analysis includes the elements described below.

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[6] A preliminary list of options was developed in line with Chapter 3, "What are the policy options?" of the European Commission's Impact Assessment Guidelines of 15 June 2005.

6.2.1 Policy options

Initially, for each of the selected products or product groups, a list of major options that are capable of achieving the objective of stopping new products from entering the market is drawn up. The main categories of policy approaches that have been considered are Community legal acts, self regulation and economic incentives. In identifying the options, existing EU policies, proposals currently under discussion in the European Parliament and Council, existing or planned Member State policies and international agreements have been considered in narrowing the options for further analysis.

6.2.2 Effects on industry

For each product group, the effects on industry have been assessed. The business impact assessment is primarily a qualitative assessment, however quantitative estimates have been included to the extent such information was obtained within the scope of the study. When assessing costs, the following issues were analysed qualitatively:

- How does the timing of the regulation affect the costs?
- How do cost elements change over time due to innovation?
- What is the relative size of the investment costs compared with the industry structure?
- What is the effect on EU trade and external trade?

6.2.3 Cost-effectiveness analysis

For each of the products or product groups a multi-criteria analysis was carried out for recommended policy options. A multi-criteria analysis compares positive and negative impacts expressed in a mixture of qualitative, quantitative and monetary terms. The cost-effectiveness analysis is supplemented with a quantification of some of the benefits. For the cost-effectiveness analysis, the approach depends on whether alternatives (or a common industry process for identifying alternatives, as in the case of catalysts for PU elastomers) are available today:

- For products or product groups where alternatives exist, the socioeconomic cost estimates are based on information on prices of mercury-containing products versus alternatives, and information on market volumes. The price of alternatives is estimated based on the price of existing alternatives combined with considerations about how use restrictions and the resulting changes in the market may affect the prices of alternatives.
- For products or product groups where commercially available alternatives do not exist today, the socioeconomic costs are estimated on the basis of the business impact assessment for these products extended with a quantification of all costs, as far as possible. The effectiveness of the different options is expressed in terms of reduced mercury going into society, and the resulting decreased amounts of mercury released to the environment and the waste streams.

Other benefits of introducing the alternatives are described qualitatively, and for selected aspects also quantitatively. As one of the important aspects of the Hg life cycle is waste treatment, the reduced environmental costs of waste management due to the use of alternatives are, to the extent possible, quantified in monetary terms by comparing the costs of waste treatment of mercury-containing products versus alternatives.

Administrative costs of implementing the policy options are not included in the analysis.

6.2.4 Summary across the policy options for all products

Based on the results of the assessment for each product or product group, a summary in tabular form, presenting an overview across all product groups, is presented in section 6.10. The overview includes, among other parameters, the results of the cost-effectiveness analyses.

6.3 Impacts on human health and the environment

According to the Global Mercury Assessment published by UNEP Chemicals, *"Mercury has caused a variety of documented, significant adverse impacts on human health and the environment throughout the world. Mercury and its compounds are highly toxic, especially to the developing nervous system. The toxicity to humans and other organisms depends on the chemical form, the amount, the pathway of exposure and the vulnerability of the person exposed. Human exposure to mercury can result from a variety of pathways, including, but not limited to, consumption of fish, occupational and household uses, dental amalgams and mercury-containing vaccines*." (UNEP 2002)

For the comparison of the cost effectiveness of different policy options, the effectiveness of the option is expressed in terms of the reduced use of mercury in marketed products. A detailed economic valuation of the human health impact of reduced use of mercury is not included in the present assessment for the following reasons.

Previous studies have demonstrated that the economic consequences of the effects of mercury exposure on human health are considerable, but the economic benefits of reduced use of mercury or reduced emissions have only been estimated within high ranges of uncertainty.

Hg uses and releases are of concern as regards the health of the general population because of two main exposure pathways: consumption of methyl mercury (MeHg) contaminated fish and inhalation of elevated concentrations of Hg vapour. The most common route of MeHg exposure for humans and wildlife is the consumption of fish from marine and freshwater sources. For a monetary valuation of the health impact of a reduced use of mercury for a certain purpose it is necessary to analyse a chain of cause and effect as illustrated in Figure 6-1 for the exposure route via contaminated fish. Each link in the chain is encumbered with significant uncertainty requiring various simplifications based on the available information.

For the link between reduced use in products and reduced releases of mercury to the environment, the question is most often the time frame of the analysis – whether the analysis includes only the present quantifiable releases associated with the use of the products, or whether the analysis also includes the long-term releases e.g. of mercury landfilled with waste. For the links in the chain describing the fate of mercury in the environment, in principle it should be possible to make an unambiguous connection, provided that enough information is available, whereby the costs of the effects of mercury on the population can be estimated, even when using basically very different costing systems.

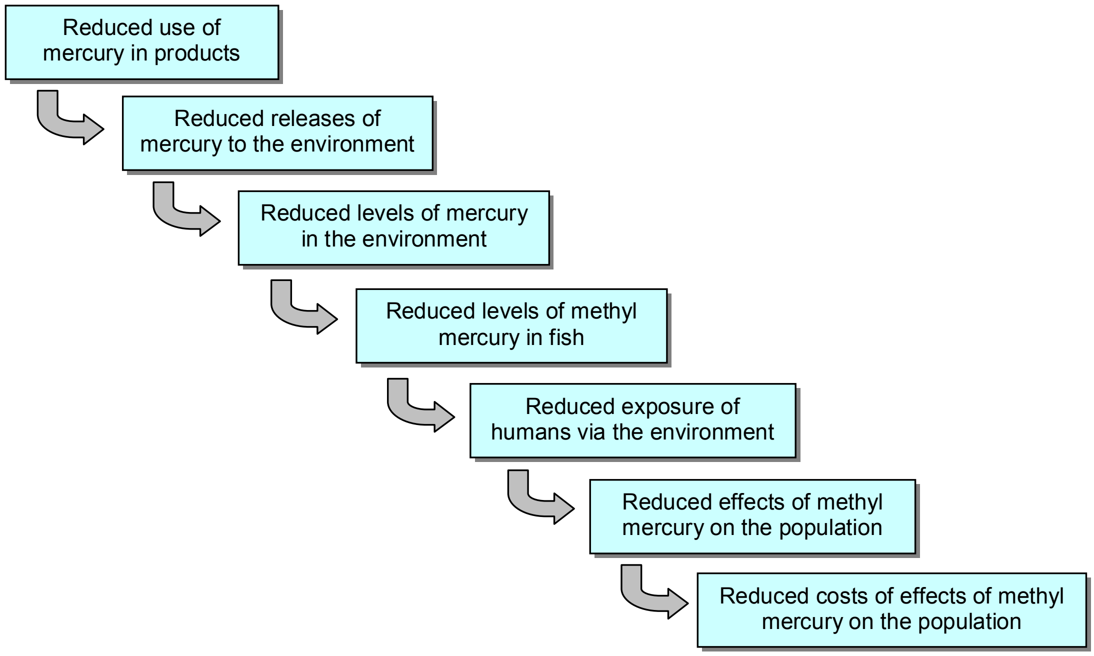

Figure 6-1 Chain of effects linking reduced use of mercury in products with reduced costs of health effects on the population caused by exposure to methyl mercury in fish.

Socioeconomic consequences of mercury uses and releases have recently been reviewed by Swain et. al. (2007). The paper reviewed the global pathways of mercury in commerce and the environment, as well as various economic analyses of mercury uses and pollution. The paper provides a summary of 11 economic analyses that have been performed of the costs and benefits of reducing mercury emissions, or simply reducing exposure through fish consumption advisories. The studies use different exposure models, health endpoints and valuation methods, and end up with quite different estimates of the costs and benefits of different policy options.

Economists employ different approaches in measuring the human health benefits associated with a policy. The cost-benefit analysis evaluates the changes in health using monetary values such as the “cost-of-illness” or the “willingness-to-pay” or the “willingness-to-accept” approaches. The cost-of-illness measures the direct costs (e.g. treatment costs) and indirect costs (e.g. foregone income) associated with illness and injury. For MeHg, the applied methods mainly link changes in the exposure of pregnant women to modelled changes in the IQ of their offspring. In some studies the MeHg exposure is also linked to nonfatal heart attacks. The willingness to pay methods measure the individual’s willingness to exchange wealth for health, e.g. the statistical value of life measures an average individual’s willingness to pay for a small delay in the probability of dying.

All of the 11 economic analyses mentioned above, conducted to quantify the benefits of reducing mercury pollution, were conducted in the USA. The impacts of the US *Clean Air Mercury Rule* (see Chapter 5) have been assessed in a number of studies, including two detailed studies by US EPA (2005) and Rice and Hammit (2005).

Swain et al. (2007) have noted that all the studies emphasized the numerous uncertainties in evaluating specific policies for mercury reduction, including *i)* changes in Hg deposition rates, *ii)* changes in levels of methyl mercury (MeHg) in fish, *iii)* changes in MeHg intake by humans and the time it takes to observe this change, *iv)* changes in IQ due to foetal exposure, and/or *v)* changes in all-cause mortality and fatal and nonfatal heat attacks in adults.

The preamble to the final Clean Air Mercury Rule issued by the US EPA (US EPA, 2005a), while seeking for political reasons to minimise the apparent socioeconomic cost of mercury emissions, cited the following general uncertainties and limitations of economic evaluations of environmental effects: "*Every benefit-cost analysis examining the potential effects of a change in environmental protection requirements is limited to some extent by data gaps, limitations in model capabilities (such as geographic coverage), and uncertainties in the underlying scientific and economic studies used to configure the benefit and cost models. Gaps in the scientific literature often result in the inability to estimate quantitative changes in health and environmental effects. Gaps in the economics literature often result in the inability to assign economic values even to those health and environmental outcomes that can be quantified.*"

US EPA's assessment estimated the total costs of the implementation of the Clean Air Mercury Rule at around USD 500 million per year; varying with scenarios and between years during the period 2010-2020. Both studies estimated the national benefits, monetised in US dollars, of quite similar scenarios for mercury release reductions in coal-fired power plants in the United States. These two studies, both of which appear comprehensive, are examples of how the results of cost assessments of an environmental problem can vary significantly depending on the approach used in the assessment. US EPA (2005) estimated the benefits of reduced IQ loss from neuro-developmental effects of prenatal exposure to methyl mercury at USD 0.03 - 3.1 million (1999) per year, depending on the threshold level for effects, the release reduction scenario, the scaling factor and the discount rate.

Rice and Hammit (2005) estimated the same benefits at USD 75-288 million per year, depending on the release reduction and exposure scenario considered. In addition, Rice and Hammit (2005) estimated the benefits of reduced cardiovascular effects (supported by less scientific consensus than neuro-developmental deficits) of exposure to methyl mercury in the US at USD 48-4,900 million per year, depending on the release reduction scenario, the exposure scenario, and the monetisation principle considered. The different estimates for the two scenarios are illustrated in Figure 6-2 showing the health benefits and the uncertainties inherent in those calculations. Scenario 1 (USD 75 million + 48 million minimum, to USD 194 million + 3.3 billion maximum in benefits) and scenario 2 (USD 119 million + 86 million minimum, to USD 288 million + 4.9 billion maximum in benefits) represent a reduction of mercury emissions from 49 tonnes to 26 tonnes and 15 tonnes, respectively, corresponding to a net reduction of 23 tonnes Hg for scenario 1 and 34 tonnes Hg for scenario 2. The annual benefits for scenario 1 can consequently be calculated at USD 5,350-151,900, or about USD 6,000-170,000 in current dollars (or €4,000 - 110,000) per kg reduction in mercury emissions.

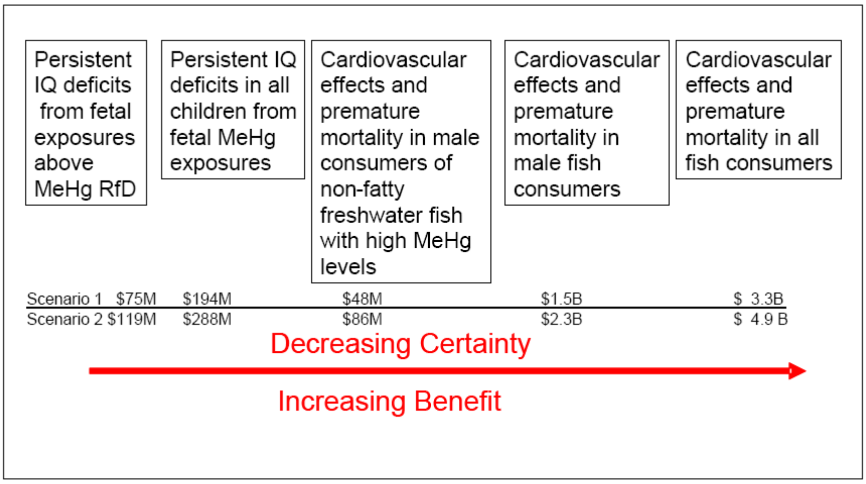

Figure 6-2 Spectrum of benefits and certainty on health effects (from Rice and Hammit 2005)

Two clear distinctions between these two studies are that the US EPA report focuses on a narrower target group of potentially exposed citizens, and only on exposure through consumption of recreationally caught freshwater fish. The US EPA report states that it considers it has included the major contributions to health benefits, but that its calculation has likely underestimated the total benefits due to reducing mercury emissions from power plants. Rice and Hammit (2005) assumed for their estimate exposures from both freshwater and marine fish. It is important to note that neither of the studies quantified environmental benefits from reduced mercury emissions – only health benefits.

Two studies of EPRI (2003) and Gayer and Hahn (2005) estimated the costs of a reduction to 15 tonnes mercury emissions from coal-fired power plants at between USD 15 (Gayer and Hahn midpoint) and USD 21 (EPRI) per capita. Gayer and Hahn, focusing solely on IQ losses, estimated the benefits of a Hg cap of less than USD 1 per capita. In contrast the study of Rice and Hammit, mentioned above, estimated the benefit at up to 16 USD per capita.

A Norwegian treatment of costs of adverse effects of waste incineration releases discusses emissions of several pollutants from this sector (ECON (2000). The estimated damage cost per gram mercury released from waste incineration is exposure-scenario-specific (*i.e.* specific for waste incineration under conditions prevalent in Norway). The cost of releases to air was assessed to be NOK 27,000-67,000 (on the order of €3,000-7,400) per kg mercury with the low-end estimate as the “main estimate”. The methodology used is based on a combination of the so-called eco-indicator 99 (Goedkkop and Spriensma 2000) and CML/RIVM indices that monetize effects on ecosystems and health. In the Norwegian study only effects on human health are taken into account as the effect on the ecosystem is considered lower and less data are available. The value of a statistical life is assumed to be NOK 12-30M. The study quotes two earlier Norwegian studies for higher estimates of the costs of emissions to the air. For releases to water the costs are estimated to NOK 3,440,000-8,600,000 per kg Hg. The exact background for the data is not presented in ECON (2000), so it is difficult to make a deeper evaluation of the derived cost estimate and how/if this includes specific and updated data on mercury’s adverse effects, a field which has experienced rapid development since the mid-1990s. The cost estimate for releases to water are specifically mentioned in the report to be much higher than the estimate in an earlier ECON study (Vennemo 1995), in which the cost of environmental externalities of releases to water and soil was estimated at €1,000 and €36 per kg Hg respectively, while the emissions to air were estimated at €25,000 per kg. The earlier study by ECON (EC 2005) is e.g. quoted in the Extended Impact Assessment of the Community Strategy Concerning Mercury.

The large differences in the cost estimates of two studies from the same institution illustrate the high uncertainties in estimating the costs of externalities.

A recently published study for the Nordic Council of Ministers (Pacyna *et al.* 2008) estimates that if no further action is taken to reduce mercury emissions globally, loss of IQ due to emissions from intentional use of mercury will lead to annual damage costs $6,4 Billion 2005 based on an assumption of a cost of approximately $12,000 per kg mercury emitted. The authors note that the total damage costs to society of mercury pollution are likely to be considerably higher since a complete set of potential costs to society was not taken into account.

As indicated above, the benefits for human health from reducing the releases of mercury can only be estimated within a high range of uncertainty. It is beyond the scope of this study to carry out basic research to further refine these estimates. In order to indicate the general range of the benefits of reducing the input of mercury to society, the possible benefits will be based on the wide range of scenario 1 of Rice and Hammit (2005), equivalent to an annual benefit of some €4,000 - 110,000 per kg reduction in mercury emissions.

6.4 Dental amalgam

Overview of consumption and fate of mercury

Table 6-1 below gives a summary of some of the key figures in the flow of mercury in the dental sector in the EU; for other data see Section 2.4. In order to estimate the effects of discussed reduction measures, additional details on the mass flows are given here, derived mainly from a report prepared by the European Environmental Bureau (EEB 2007). The total use of mercury in the EU every year is in this study estimated at 80-110 tonnes, and the average figure is, in combination with emission factors from the EEB study, used to estimate the amount of mercury following the different pathways.

Table 6-1 Selected mercury flows associated with dental amalgam

	Mercury flow 2007, tonnes Hg	% of Hg output *1
Yearly consumption	80-110	
Intermediate fate of amalgam (including mercury from old fillings):		
Retained by simple traps in clinic	23	24
Retained by separators in clinic	18	19
Lost directly to atmosphere	5	5
Disposed to municipal waste	17	18
Discharged as wastewater	22	23
In cremated bodies	4	4
In buried bodies	7	7
Sum	95	100

*1: Emission factors (percentages) based on EEB 2007.

Alternatives to dental amalgams

As described in section 2.4.4, several mercury-free dental restoration materials are generally available on the market in EU Member States. The dominating alternatives have the benefit of being coloured like the teeth, a characteristic preferred by users for cosmetic reasons. As composite filling materials appear to be dominating the market, and as they are generally accepted as a substitute for mercury amalgam in most dental restoration situations, only these materials are included in the further evaluation. The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR 2008) has concluded "that dental health can be adequately ensured by both types of materials"; that is, amalgam as well as the available alternatives.

SCENIHR also summarises their detailed review as follows: "*Alternatives to amalgam have been in clinical use for well over 30 years. They have not only addressed the issues on the aesthetics of amalgams but have facilitated a radical change in the concepts of restorative dentistry through the introduction of more minimally invasive techniques and the associated retention of more tooth substance when treating caries(....) It is recognised that their use may be technique sensitive and that the procedures for their placement may take longer and therefore be more expensive. It is also true that they may be more susceptible to secondary caries and, in some situations, have less longevity than amalgams. In general therefore these tooth coloured alternatives offer an effective modality for the treatment of dental caries in most situations." "It should not be assumed that non-mercury-containing alternatives are free from any concerns about adverse effects (……….). Nevertheless, these alternative materials have now been in clinical use for well over thirty years, and this use has revealed little evidence of clinically significant adverse events. The commercially available materials have either changed substantially or been improved considerably during this time, with reduced bioavailability of harmful components through improved polymerisation processes. It is recognised that many of the new forms of these alternative materials lack long-term clinical data and as such, need to be monitored for possible risks to patients and dental personnel. As a separate issue, it should be borne in mind that these photo-polymerisable systems require activation and that the powerful light sources now used for this purpose may constitute an additional risk for adverse effects, both to patients and dental personnel. Eye protection is extremely important.*"

Current community level legislation and other measures
No community legislation currently regulates the use of mercury amalgam fillings in dental preparations. Dental amalgam waste include mercury which render the waste hazardous according to the Hazardous Waste Directive.

Legislation beyond EU legislation in force in Member States, Norway or Switzerland
The use of mercury in dental filling materials is prohibited in Denmark, The Netherlands and Norway as part of these countries' general bans on mercury. Exemptions exist in the Danish prohibitions for fillings in permanent molar teeth, where the filling is worn. Exemptions exist in the Norwegian prohibitions for patient treated under general anaesthesia or who are allergic to ingredients in other dental fillings.

In the following, two groups of options for preventing releases of mercury to the environment and exposure of humans will be analysed:

- Options for preventing mercury in new products;
- Options for improved management of mercury already in circulation.

6.4.1 Options for preventing mercury in new products

Policy options for preventing the mercury use in dental amalgam are listed in the table below.

	Option		Effect on mercury in new products
Community legislation	a1	General ban of the use of mercury in any form for preparation of dental fillings, with exemptions for specific applications	Reduce input with: 80-110 tonnes annually
	a2	Prohibition of specific applications of dental amalgam (e.g. in milk teeth)	Limited reduction expected for milk teeth (DK experience ~ 14% reduction).
Economic incentives	b1	Environmental fees on prepared amalgam fillings	More limited reduction, as it would allow some dentists to continue use.
	b2	Removal of subsidies for amalgam fillings in health insurances	More limited reduction, as it would allow conservative dentists to continue use. Only relevance in countries with public subsidies for dental care.

Policy options selected for further analysis

Option a1: "General ban of the use of mercury in any form for preparation of dental fillings, with exemptions for specific applications" is expected to be the simplest and most effective measure. It will produce the most significant mercury input reductions and will imply the least public administration efforts among the options listed. This option was selected for further assessment.

Depending on the extent of exemptions, this reduction option has the potential for eliminating all/most of the mercury inputs and releases from dental amalgam use. Due to the mercury amounts already accumulated in the teeth of European citizens, mercury releases to the environment and to waste disposal from this sector will continue for an anticipated 15-20 years after the elimination of new mercury inputs.

6.4.2 Impact and costs of preventing mercury in new products

The table below provides an overview of the main impacts and cost elements for the action proposed. The impact analysis will in particular focus on the qualitative elements.

Table 6-2 Impacts and costs of prohibiting mercury use in dental preparations

Life cycle phase	Impact elements	Cost elements	Benefit elements
Manufacturers	Impact on manufacturers of Hg-containing filling materials	Decreased sale of dental amalgams Costs of increasing the capacity for manufacturing of alternatives *1	
	Impacts on manufacturers of Hg-free filling materials		Increased sale of alternatives
Trade of products	Impact on global market		Further boost of global market for alternatives Decreasing prices of alternatives due to increased competition and production efficiency
Users of the products - dental customers	Impacts on the price of dental restoration	Higher costs due to higher price of preparing fillings with alternatives Costs of more frequent renewal of the fillings due to shorter life of alternative fillings in the mouth.	
	Impacts of exposure of humans and the environment		Reduced costs of environmental and health impacts of mercury released from the entire life cycle of dental amalgam fillings (during preparation, releases from mouth, from sewage and via waste)
Users of the products - dentists	Health impact for dentist personnel		Reduced/eliminated health effects for clinic personnel's handling of hazardous mercury waste
	Impact on sewage management in dental clinics		Reduction, and in the long term elimination, of costs for installation and maintenance of amalgam separators
Society	Impact on public sewage sludge management		Reduction of costs for special deposition of sludge which cannot be used as fertilizer due to elevated Hg concentrations
	Impact on solid waste disposal		Reduced costs from releases of mercury waste going to MSW from dental clinics and from homes (with lost teeth). Reduced costs of selective collection and treatment of mercury-containing dental waste
Crematoria	Impact on releases from crematoria of mercury in dental fillings		Reduced costs of having mercury filters on crematoria

*1 Based on the available information, almost all manufacturers of mercury amalgam filling materials in the EU also manufacture alternatives. This also implies that manufacturing procedures are already well incorporated and no special training or conversion activities are necessary besides a general increase in production capacity. Export out of the EU of mercury-containing dental filling materials may stay stable or increase as the European market is reduced, unless restrictions on export are imposed.

Impacts on EU manufacturers

As observed in section 2.4, all but two of the 25 EU producers and suppliers of dental filling materials identified supply the mercury-free alternatives, and all 12 identified EU producers of amalgam capsules also produce alternatives. Furthermore, a shift towards the alternatives may shift the marked volume from imported products towards products produced in the EU with a potential for increased EU income. At the same time, amalgam capsules are exported from the EU. In case export of amalgam capsules are not restricted in the future, substitution within the Community is therefore expected to have positive or minimal economic impacts on EU manufactures of dental fillings materials.

In case exports of dental amalgam capsules should be restricted, EU manufactures will need to shift production capacity from amalgam capsules towards production of the alternatives with resulting costs. Some industry concern has been raised that access to European produced amalgam capsules provide lower-income countries with a safer product than the present general practice of mixing liquid mercury in the open in the clinics.

Impacts on dental customers

Composite filling materials may be somewhat more expensive than amalgam filling materials; the materials used contribute however only minimally to the total dental restoration price in EU conditions. KemI (2004) reports that material costs for fillings (in Sweden) contribute about 5-10% of the treatment costs, irrespective of the type of material, while salary costs amount to almost three-quarters of the total costs of the Swedish National Dental Service. KemI also reported patient price ranges in Sweden for single surface fillings for amalgam at SEK313-610 (€53-66) and for alternative materials at SEK358-625 (€39-68), indicating no significant differences in patient prices for simple surface fillings. It should be noted however, that in Sweden, only restoration work with alternative filling materials is publicly subsidised, and not amalgam fillings. Subsidies vary between local counties, so the price ranges for Sweden given here cannot be compared directly with those given for other countries in this section.

In Denmark standard prices negotiated between the National Health Insurance and the Dentists Association apply for all amalgam fillings (in molar teeth) while for alternatives, only for simple single surface fillings. For amalgam single surface fillings the total cost is DKK 227 (€30), while the comparable price for composite fillings is DKK 406 (€54); a factor 1.8 times higher. For 2 and 3 surface fillings, no standard prices apply. Examples from two dental clinics contacted in this study revealed average prices for 2 surface fillings in molars for amalgam at DKK 315 (€42) and for composite DKK 960 (€128); a factor of 3.1 higher. In one example, the dental clinic charged DKK 503 (€67) for a 3 surface amalgam filling, while the price for composite was DKK 1218 (€162); a factor of 2.4 higher. Actual patient prices are somewhat lower due to public subsidies for dental care. The subsidies appear however to be based on the cheapest filling materials prices where alternatives exist (in molars), with the consequence that subsidies are relatively high for amalgam and relatively low for alternative filling materials.

Examples collected for this study at two Belgian dental clinics showed single surface prices at €10 and €18 respectively for amalgam, while comparable composite fillings cost €10 and €25 respectively; meaning that at one clinic the same price was charged for amalgam and composite,[7] while at the other clinic composite fillings were 1.4 times more expensive than amalgam. For the clinic with formal price differences, two surface fillings cost €20 for amalgam and €30 for composite, whereas 3 surface fillings cost €28 and €43, respectively (factor 1.5 differences in both cases). These prices were characterised as high end prices for the Belgian situation.

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[7] While the formal price charged by this clinic for amalgam and composite fillings was the same, it was mentioned that the clinic typically added a surcharge when extra time was required to place a filling.

The higher prices for composite fillings are mainly due to the fact that today's composite fillings must be prepared in a sequence of thinner applications with intermediate curing of the polymer resin. Future technology improvements may possibly reduce the labour intensity of composite fillings. In Member States with generally lower labour price levels than Sweden, Belgium and Denmark, the price differences between preparation of amalgam and composite fillings may be lower than in the cited examples.

For some filling types, alternative fillings may have shorter lifetimes than amalgam fillings. Consistent, quantitative evidence of this factor have however not been identified in the preparation of this assessment, and it has consequently not been included in the calculations made.

A very roughly estimated range of the potential EU-wide increase in consumer prices can be calculated using the price examples given here. It is underlined that the price examples vary quite a lot, and that representative price examples from other Members States would increase the relevance of the estimate; it does however give a rough indication of the potential costs. As seen, prices vary with filling size. Detailed data from Denmark showed a consistent distribution among filling sizes performed in private dentistry (serving all except school children) in the years 1999-2001, namely approximately ¼ single surface fillings, approximately ½ two surface fillings, and approximately ¼ three surface fillings (Christensen *et al.* 2004). Combining this distribution with averages of the few price examples given, a hypothetical mean price increase per filling, when shifting from amalgam to composite fillings, can be calculated at €39. Considering the scarce data and the probable lack of representation, it appears reasonable to assume a large range of €10-70 extra per average filling. Assuming a mercury consumption of around 0.9 g per average filling (including waste) as found in Denmark (Christensen *et al.* 2004), this cost corresponds to about €10-80 per gram mercury not sent into circulation in society with resulting eliminated releases and exposures. Substituting the 80-110 tonnes of mercury in dental amalgam with composite fillings could thus, using the assumptions made here, result in an increase in total dental filling consumer prices[8] in the range of app. 1-10 billion €/year. The costs corresponds to a costs of approximately €2-20 per capita per year. Potential price drops at higher consumption of composites are not considered in this calculation. The higher price of alternatives are mainly due to the higher salary costs and a lower price of the dental fillings due to price drops would have a small impact on the actual price of the fillings. Development of new faster techniques for preparation of the alternative fillings may result in lower prices, but no information on the prospective of development of new techniques has been available. The data and results involved in the calculations are outlined in Table 6-3 below.

Table 6-3 Key figures in the estimation of increased costs of substituting composite fillings for amalgam.

Number of Hg fillings substituted EU27+2:	Low-end	High-end
Current Hg consumption, dental, g/y	80,000,000	110,000,000
Number of fillings at 0.9 g Hg/filling	88,888,889	122,222,222
Price increase per g Hg substituted, €	11	78
Total cost increase, EU27+2, €	1,000,000,000	9,500,000,000

The extra one-time investments in equipment at the dental clinics for preparation of polymer-based fillings are minimal as only a polymer curing lamp is needed (price range in Sweden in

[8] Subsidies, if any, are not subtracted.

2004 app. €540-1,630, according to KemI, 2004). However it would be reasonable to assume that most clinics are already in possession of such equipment.

In the case of full substitution (with limited exemptions), costs for amalgam filters/separators and special waste handling will be reduced over approximately two decades as the inventory of amalgam fillings already in peoples' mouths will be eliminated. In addition, the dental clinic's cost for handling solid amalgam wastes will be reduced. These effects imply the potential for minor price reductions for consumers for dental restoration work. Based on the data presented below in the discussion of costs for obligatory installation of amalgam separators/filter, the total costs that could be eliminated for amalgam separators/filters by the substitution of amalgam fillings can be estimated at around €15-25 million per year.

Impacts on waste disposal and public sewage management
Besides the cost savings from management of the mercury in the dental clinic mentioned above, the substitution of mercury in dental fillings may reduce the efforts and costs of managing mercury wastes in public municipal waste handling. These are costs which are today largely born by the general public and not by the waste producers (the dentists). In addition, costs may be saved in the public sewage treatment systems (also today paid by all general users), if more sewage sludge will have low enough mercury concentrations to be applied as fertilizer in agriculture, and does therefore not need the more costly special treatment or deposition applied in cases of excess mercury concentrations today. Is has, however, not been investigated to what extent mercury in the sludge is limiting factor for the use of the sludge for agricultural applications.

Impacts on crematoria
Amalgam fillings give rise to mercury releases from crematoria and cemeteries. In some countries which have minimized other mercury releases, crematoria are among the major remaining release sources. Some Member States have issued national regulation prescribing mercury retention equipment on crematoria flue gas outlets. Substitution of amalgam fillings will in the long run eliminate the need for investments and service on rather costly mercury filters on crematoria.

Costs for installation and maintenance of filter for retention of mercury and dust from crematoria were summarised by Schleicher and Gram (2008) based on Danish and British examples. The examples included the installation of bag filters with carbon injection, which is deemed the most relevant technology, and adaption/extension of buildings to house installations. Typical costs for filter installation were reported to be around 3.3 million DKK (€0.44 million) per filter serving one oven, and DKK5 million (€0.67 million) per filter serving two ovens, plus on average 0.75 million DKK (€0.1 million) per installation in Denmark for needed building adjustments/extensions (range 0.2-1.8 million DKK). Maintenance costs were estimated roughly for Danish conditions at 13-20 DKK (app. €2-3) per cremation performed, including consumed carbon and fees for disposal of used carbon as hazardous waste. British maintenance costs were estimated at £15-20 /cremation (app. €20-27). Cheaper and more expensive examples of filter installations are reported to be available; their suitability being dependent of the actual situation. Mercury retention technology involving carbon injection or carbon fixed beds also retain parts of the dioxin emissions from crematoria. According to these authors, filter installations for crematoria are more expensive than similar industrial installations because they need aesthetical housing and because a visible flue gas plume is not desired.

The bag filters also act as dust retention which is required in some countries. For crematoria which already have suitable bag filters installed and have room for extra equipment, the addition of a carbon dispenser would involve only limited extra installation costs; around DKK100,000 (around €13,000), plus the same maintenance costs as mentioned above (Schleicher and Gram 2008).

The same report estimates the total costs of equipping the full Danish crematoria capacity with the above described filter configuration at DKK99 million (€13.3 million; 22 crematoria excluding a few crematoria which are considered in excess in the future). No data have been identified on the expected life of the relevant type of filter installations; to enable indicative calculations Based on information from filter suppliers, around 15 years is the expected technical life for the relevant filter installation types. The actual filter bag have a life of typically 3 years and need to be exchanged; this is however assumed to be included in the British maintenance costs mentioned above. With 41,000 annual cremations in Denmark (as in 2001, Christensen et al. 2004), installation costs alone correspond to DKK160 (€22) per cremation, or €8 per g mercury captured, at 90% Hg filter efficiency and 3 g Hg/deceased person currently, see section 2.4). Adding maintenance costs conservatively using the British numbers above, the estimated total costs are around €45 per cremation, correspondingly around €17 per g mercury retained.

With around 1.4 million cremations performed annually (Cremation Society of Great Britain 2004), this adds up to a total cost for filtering at all crematoria in EU27+2 of around €62 million. Note that this also includes crematoria that have already invested in mercury filters. The total mercury releases from crematoria are estimated at 4 tonnes.

Impacts on human health and the environment
Neither mercury amalgam nor the alternatives are devoid of the potential for adverse effects on health and the environment. Adverse effects on humans and the environment in the whole life cycle of dental amalgam, mercury production, preparation of fillings, potential effects while in the mouth (if any), and impacts from sewage discharges, waste disposal and releases from crematoria and cemeteries, can be avoided by the substitution of mercury as a dental restoration material.

Substitution of dental amalgam will prevent an annual 80-110 tonnes of mercury from entering the market, of which a substantial portion is released to the environment directly or indirectly in subsequent life cycle phases (see section 2.4).

6.4.3 Options for improved management of mercury already in circulation

Policy options for improved management of mercury already in circulation are listed in the table below.

	Option		Effect on mercury releases
Community legislation	a1	Obligatory application of high efficiency amalgam separators in dental clinics	Direct releases retained and converted to solid waste: 19 tonnes/y
	a2	Obligatory application of high efficiency amalgam separators in dental clinics Obligatory filter/piping installations inspection, filter replacement and documented waste disposal, certified by accredited filter service suppliers *1	Direct releases retained and converted to waste: 21 tonnes/y
	a3	Obligatory application of amalgam filters in dental clinics and dedicated storage of amalgam waste	As a1 (or a2 if desired) plus safer/terminal storage of waste with reduced potential for subsequent releases from use of re-marketed recycled Hg
Economic incentives	c1	Environmental fees on mercury releases from dental clinics or on mercury content in sewage sludge (encouraging sewage operators to intensify mercury reductions at dental clinics)	More limited reductions than a1 are expected, due to more complicated control procedures.

*1 Modern filter suppliers also contract for filter maintenance and waste management in Denmark, but it has not been investigated whether it is general in MS. [According to the Hazardous Waste Directive, handlers of mercury waste must already be registered and approved by the environmental authorities. Certification and accrediting for installation and inspection of filters and piping is new. Similar certification by suitably educated and accredited sewage personnel exist today for general sewage piping works at least in some countries.

Policy options selected for further analysis

Option a2: “Obligatory application of high efficiency amalgam separators in dental clinics. Obligatory on-site filter/piping installations inspection, filter replacement and documented waste disposal, certified by accredited filter service suppliers” is expected to secure the most effective reduction of mercury releases to wastewater from the dental sector, as long as the use of amalgam fillings is not banned or severely restricted. This option was selected for further assessment. The question of dedicated storage of amalgam waste will be similar to the general considerations of terminal storage of medium concentration mercury waste and will not be analysed further here.

This reduction option has the potential for reducing the mercury releases to wastewater shown with up to around 95-99%. Choosing option a1 would reduce these releases somewhat less, around 80-90%, due to lower efficiency resulting from less optimal installation and/or lacking maintenance, based on Hylander *et al.* (2006, 2006b).

6.4.4 Impacts and costs of improved mercury management

Main impact and cost element of selected policy options

Table 6-4 identifies the main impacts and cost elements for each of the actions proposed. The impact analysis will in particular focus on the qualitative elements.

Table 6-4 Impacts and costs of prohibiting mercury use in dental preparations

Life cycle phase	Impact elements	Cost elements	Benefit elements
Manufactures	Impact on manufacturers of amalgam separators		Increased sales of amalgam separators unless Dental clinics start to swift to non Hg filling material
Dentists	Impacts on sewage management in dental clinic	Costs for installation, maintenance and certification of amalgam separators (also indirectly covering costs for waste treatment and training of accredited personnel)	
Society	Public sewage sludge management		Reduced costs of special deposition of sludge which cannot be used as fertilizer due to elevated Hg concentrations
	Waste disposal		Reduced costs of treatment/disposal capacity for mercury-containing dental waste
	Impacts of exposure of humans and the environment		Reduced costs of environmental and health impacts of mercury released via sewage and waste

Impacts on EU manufacturers

Obligatory use and inspection of efficient dental amalgam filters will have a positive economical impact on producers and service providers supplying and maintaining the filters, as their sales will increase. See below for assessment of the economic potential (increased expenses for dental clinics).

Impacts on dentists and dental customers

For dental clinics which do not have high efficiency amalgam filters/separators installed, Obligatory installation and maintenance will be an extra cost. Based on a price example from Denmark, the costs per clinic is around DKK 3,000 annually (approximately €403/y) for a full installation and service package; a minimal cost considering the expense level for labour and other equipment in the dental clinics. Similar price levels are reported from the USA (PACE 2004). This price does however not comprise in-situ evaluation of filter efficiency and accreditation of the services (today, only the filter units are certified in lab scale tests), and such additional services could raise the costs somewhat. Based on chemical analysis price levels, a total price for the full, accredited service is not expected to add much to the prices[9], and a price level of €400-500 per clinic per year seems realistic. These expenses will most likely be reflected in consumer prices (KemI 2004). On the other hand, the principle 'the polluter pays' is in line with current EU policy thinking concerning internalisation of external costs. It would also give the

[9] Unless regular in situ efficiency analysis should happen to reveal that more frequent maintenance visits than one annual visit are actually needed.

dental clinics a direct economic incitement to swift to alternative products not requiring the separator filter system.

Considering the available estimates of current coverage with high efficiency filters, app. 30-40% (section 2.4), and an estimated total of some 130,000-210,000 dental clinics (based on data in section 3.1.4), some 80,000-150,000 dental clinics would need to have separators/filters installed in case this became obligatory. Using the cost estimate above per clinic, this would equal a total extra expense of some €30-80 million in the EU27+2. If this measure can retain some 21 tonnes mercury from discharge per year, as indicated above, this cost would equal some €1.4-1.8 per g Hg.

In addition, with the assessed option a2, the costs of in-situ evaluation of amalgam separator efficiency, and accredited maintenance, needs to be estimated for the dental clinics which have these installed already. Using the numbers given above some 50,000-60,000 dental clinics are expected to have amalgam separators installed. Estimating the added costs for in-situ evaluation and accredited service at around €100 per year, the total increased cost would be around €5 million annually.

Impacts on waste disposal and public sewage management

Mercury from dental clinics represent in many countries the main source of mercury to the municipal sewage system (ICON 2001). The improved management of the mercury in the dental clinic may reduce the efforts and costs of managing mercury wastes in public municipal waste handling. These are costs which are today largely born by the general public and not by the waste producers (the dentists). In addition, costs may be saved in the public sewage treatment systems (also today paid by all general users), if more sewage sludge will have low enough mercury concentrations to be applied as fertilizer in agriculture, and does therefore not need the more costly special treatment or deposition applied in cases of excess mercury concentrations today. Is has, however, not been investigated to what extent mercury in the sludge is limiting factor for the use of the sludge for agricultural applications.

The mercury retained in the filter must be collected and undergo special waste treatment, but in this case, the waste handling costs will be paid by the polluters (the dental clinics as described above).

The potential cost savings are not documented but are likely larger than the €30-80 million at combined EU level as was the additional costs of installing the separator filters at the Dental clinics.

Impacts on human health and the environment

Adverse effects on humans and the environment can be reduced by the full implementation of effective amalgam filters/separators, provided the mercury-containing filter material is collected and treated carefully to minimize mercury mobility and exposure, as prescribed by current EU waste regulation (and potentially by new regulation on safe storage of these types of mercury-containing waste).

As shown above, for option a2 an estimated maximum of 21 tonnes of mercury will be retained from releases to the sewage system and converted to hazardous waste. This can be related to a total input of mercury with dental care of 80-110 tonnes/y. Based on general experience, it must be anticipated that actual retention will be less than the maximum value due to cases of missing compliance.

The assessments of the costs of mercury releases mentioned in section 6.3 mainly concern atmospheric releases. The mentioned Norwegian study also provide some estimates for releases to waste, but these estimates are considered to be based on a very uncertain ground. Consequently, it has not been attempted to undertake any quantification of the health benefit of this policy option.

6.4.5 Conclusions

The following Table 6-5 gives an overview of the main cost elements involved when considering the described release reduction options for dental amalgam. The table also summarises the quantified cost elements and gives an indication of the expected weight of cost elements not quantified in this study.

Substitution of dental amalgam is no doubt effective as it would eliminate the total input of mercury to this sector, and thus eliminate in a few decades the adverse impacts of mercury releases resulting from this activity. As the table shows, the cost level - however roughly estimated only - indicate a rather substantial cost for the substitution of dental amalgam with composite fillings, the most widely used alternative today. This should however be consider in perspective of a number of cost elements which have not been possible to quantify within this study. Expected benefits from reduced adverse effects of mercury releases and reduced costs for mercury waste management in all associated flows in society are expected to be major contributions. Both are however complicated to estimate. Current estimates of health benefits per gram mercury reduced are considered very uncertain and imply the risk of serious misinterpretations.

The costs of emission reduction of one kg mercury in crematoria is in the same range as the lower estimate of the costs of substitution of dental amalgam.

It is clearly indicated that applying high efficiency filters and maintenance requirements is a quite cost effective measure, with a price per kg mercury release reduction of only 1/10 of the costs of reduction the releases from crematoria.

Because of the large quantities of mercury accumulated in the teeth of the population, substitution and “end-of-pipe” measures are, in the short term, not so much possible alternatives; rather both measures are necessary at the same time. Over the longer term, of course, the “end-of-pipe” measures would no longer be needed as dental mercury no longer reaches any waste stream in significant quantities.

Table 6-5 Overview of the main socioeconomic cost elements assessed in this study with regard to mercury use in dental amalgam

	Impact element	Costs compared to the use of dental amalgam	Benefits
Dental customers	Costs of substitution of amalgam due to higher price for preparing fillings with alternatives	€1,000-10,000 million/y (€11,000-78,000 per kg Hg use reduction)	Eventual health benefits of not having mercury fillings is controversial - SCHER (2008) concludes that that dental health can be adequately ensured by both amalgams and alternatives
Dental practices (price indirectly allocated to dental customers)	Costs of applying high efficiency filters and maintenance requirements	€15-25 million/y (€1,400-1,800 per kg Hg release reduction)	
	Reduced/eliminated costs for clinic personnel's handling of hazardous mercury waste		Eliminated health risk for dental personnel
Society	Costs of having mercury filters on all crematoria (of which some already have filters)	€62 million/y *1 (app. €17,000 per kg Hg release reduction)	
	Costs from releases of mercury waste going to MSW from dental clinics and from homes (with lost teeth).		Cost savings
	Reduced environmental and health impacts of mercury released from the entire life cycle of dental amalgam fillings (during preparation, releases from mouth, from sewage and via waste)		Not assessed, but may be significant

6.5 Measuring equipment for professional use

As demonstrated in section 2.5 mercury is used for a number of applications in measuring equipment. The main application areas are today sphygmomanometers, thermometers and barometers. For other measuring equipment the mercury-containing equipment is mainly (or exclusively) used for laboratory analysis and research and the mercury quantities are small.

Sphygmomanometers

The market of mercury sphygmomanometers has been decreasing in recent years and the total mercury content of sphygmomanometers sold in the EU in 2006 is estimated at about 3-6 tonnes. The level of substitution varies among countries. According to a major manufacturer Italy and the Eastern European countries constitute the largest market for mercury sphygmomanometers within the EU, whereas the mercury sphygmomanometers in the other Member States account for 10% or less of the total market for manual blood pressure measurement devices (devices for blood measurements using the auscultatory method). Mercury sphygmomanometers are mainly requested by general practitioners.

Thermometers
Based on information obtained from a number of thermometer manufacturers it is estimated that the mercury content of mercury-in-glass thermometers marketed in the EU for use in laboratories and for specific purposes in the industry is in the order of 0.6-1.2 tonnes per year. It is estimated that approximately half on the mercury is used in thermometers for laboratory use, and the other half used for industrial and marine applications. Mercury has been replaced by alternatives for most industrial and marine applications, but mercury-in-glass thermometers seems to hold a significant market share for some specific applications.

The mercury content of marketed mercury-in-steel dial thermometers used in the industry and marine applications is estimated at 0.1-0.3 tonnes mercury per year and mercury can be replaced for all applications.

Barometers
Compared to sphygmomanometers and thermometers, barometers account for a minor part of mercury in measuring devices for professional uses. The major part of the mercury barometer market has been for household use, and this application cease by October 2009. The mercury use for barometers for professional applications is estimated at 0.1-0.5 tonnes per year. The market for mercury barometers has been decreasing and the mercury barometers for professional applications hold today a very small market share, and alternatives are available for all applications.

Current community level legislation and other measures
Measuring devices intended for sale to the general public and fever thermometers for all applications may according to Directive 2007/51/EC of 25 September 2007 amending Council Directive 76/769/EEC not be placed on the market by 3 April 2009. According to the directive, by 3 October 2009 the Commission shall carry out a review of the availability of reliable safer alternatives that are technically and economically feasible for mercury-containing sphygmomanometers and other measuring devices in healthcare and in other professional and industrial uses. On the basis of this review or as soon as new information on reliable safer alternatives for sphygmomanometers and other measuring devices containing mercury becomes available, the Commission shall, if appropriate, present a legislative proposal to extend the restrictions in 2007/51/EC to sphygmomanometers and other measuring devices in healthcare and in other professional and industrial uses, so that mercury in measuring devices is phased out whenever technically and economically feasible.

Legislation beyond EU legislation in force in Member States, Norway or Switzerland
The Netherlands has a general ban of possessing or use for trading or production of mercury in products including measuring devices. The regulation has an exemption for mercury thermometers exclusively intended to perform specific analytical tests according to established standards.. Sweden has a general prohibition of mercury in measuring equipment, but has an exemption for thermometers used for flash point determination in accordance with ASTM standards. Denmark has a general prohibition on import, export and sale of mercury and mercury-containing products. The regulation has an exemption for thermometers and barometers for calibration of other equipment and thermometers used for analysis. Further products for research and teaching are exempted. Sphygmomanometer is beyond the scope of the regulation. Norway has a general prohibition on production, import, export, sale and use of mercury in products. The regulation does not have any exemptions for measuring equipment.

6.5.1 Main options for reducing or preventing mercury in new products

Policy options for reducing mercury use in sphygmomanometers are listed in the table below. Self-regulation and economic incentives are not considered relevant options for this product group.

	Option		Effect on mercury in new products
Community legislation	a1	Extent the ban on liquid mercury in measuring devices in 76/769/EEC to include placing on the market of all measuring devices for professional use 76/769/EEC has a general exemptions for marketing or use for Research and Development or analysis purposes.	Reduce mercury input by: Sphygmomanometers: 3 - 6 tonnes Hg/year Thermometers: 0.2 - 0.6 tonnes Hg/year Barometers: 0.1 - 0.5 tonnes per year Total: 3.3 - 7.1
	a2	Extent the ban on liquid mercury in measuring devices in 76/769/EEC to include placing on the market of measuring devices for healthcare	Reduce mercury input by: Sphygmomanometers: 3 - 6 tonnes Hg/year Total: 3 - 6 tonnes
	a3	General ban on liquid mercury in measuring devices	Reduce mercury input by: Sphygmomanometers: 3 - 6 t tonnes Hg/year Thermometers: 0.7 - 1.5 tonnes Hg/year Barometers: 0.1 - 0.5 tonnes Hg/year Total: 3.8 - 8.0 tonnes Hg/year
	a4	General ban of export of mercury in measuring devices (in addition to a1 or a3)	Reduce mercury export from the EU with Sphygmomanometers: 5 - 8 tonnes Hg/year Thermometers: 0.5 - 0.8 tonnes Hg/year Barometers: 0.2 - 1.0 tonnes Hg/year Total: 5.7 - 9.8 tonnes Hg/year
	a5	Doing nothing	The mercury use for measuring devices has been decreasing, but mercury-containing measuring devices, in particularly thermometers, will probably remain on the market for many years to come
Self-regulation	b1	No options assessed	
Economic incentives	c1	No options assessed	

Both option a1 and a2 would be consistent with existing EU legislation as they can be implemented by an amendment to 76/769/EEC, the difference is whether only healthcare or all professional applications are addressed. The Community Strategy Concerning Mercury specifically describe that the Commission intends to restrict the marketing for consumer use and healthcare of nonelectrical or electronic measuring and control equipment containing mercury which would mostly be in line with option b.

The difference between option a1 and a3 is that a1 has a general exemption for Research and Development or analysis purposes whereas a3 cover all applications of the equipment.

For some applications it may be difficult to determine to what extent the application falls under the definition of “analysis”. The definition “analysis” is quite straight forward for chemicals as “analysis” in this case implies that the chemical is used for the determination of a chemical or physical property of a medium. In the case of measuring equipment the application of the equipment is in any case to determine a physical property of a medium. “Analysis” may in this case alternatively be defined in line with the exemption for thermometers to the Dutch regulation: Equipment exclusively intended to perform specific analytical tests according to established standards. It may also be considered to include equipment used for calibration of other equipment in line with the exemptions in the Danish regulation.

Using this definition most uses of sphygmomanometers and barometers would not be exempted, whereas a significant part of the use of thermometers would be exempted. The thermometers for analysis would comprise thermometers used in laboratories and used in the industry for process control in accordance with standards e.g. the ASTM or DIN standards used in the petrochemical industry. In total these applications account for more than half of the use of professional, non-medical mercury thermometers. Use of mercury sphygmomanometers in research programmes in specialised cardiological departments may also be defined as “research and development” and for such research the use of mercury sphygmomanometer may be of importance for the comparison of results with previous research results, however no information that mercury sphygmomanometers are actually requested by cardiological departments has been identified.

In total, the difference between a1 and a3 in terms of mercury reduction is quite small representing about 15% of the mercury consumption for this application area. The mercury reduction by option a2 would be another 20% less than option a1.

The mercury input for measuring devices has been steeply declining in recent years, but it is estimated that the mercury input with this equipment, if not regulation (option a5) may slowly decrease to half of the current level, but mercury-containing measuring devices will be marketed for many years to come.

Policy options selected for further analysis

It is regarded that the policy options most consistent with existing EU legislation are a1 and a2: Extent the ban on mercury in measuring devices in 76/769/EEC to include either all measuring devices for professional use with the general exemptions for Research and Development or analysis purposes or to include only all equipment used for healthcare. These two options will be selected for the further assessment.

If the use of mercury-containing measuring equipment is prohibited in the EU a general ban of export of the equipment would be a possibility and in line with the export ban on mercury soaps and liquid mercury. The assessment include some considerations regarding the impact on European manufacturers but a full assessment is not done for option a4.

Main impact and cost element of selected policy options

The tables below provide an overview of the main impacts and cost elements of the actions proposed. The impact analysis will in particular focus on the qualitative elements.

Table 6-6 Impact and cost elements of prohibiting marketing of mercury in measuring equipment

Impacts on:	Impact elements	Cost elements	Benefit elements
Manufacturers	Impact on manufacturers of mercury-containing equipment	Reduced sale of mercury measuring equipment	
	Impact on manufacturers of mercury-free equipment		Increased sale of mercury-free equipment
Users of the equipment	Impacts on the price of equipment	Increased costs due to higher price of alternatives (dependent on actual equipment)	
	Impact on the reliability of blood pressure measurements	Costs of more frequent calibration (dependent on actual equipment)	
	Impacts of spill of mercury		Reduced costs of mercury spill kit and spill response preparedness/training Reduced costs of clean up of mercury spill
	Waste disposal	Costs of selective collection and treatment of electronic equipment (for electronic devices)	Reduced costs of selective collection and treatment of mercury-containing equipment
Society	Impacts of spill of mercury		Reduced costs of health impacts of mercury in the indoor environment Reduced costs of environmental impacts of mercury releases from the spill
	Waste disposal		Reduced costs of environmental and health impacts of mercury released from waste operations and landfills

6.5.2 Sphygmomanometers

The following section include a description of the impacts on manufacturers and users of sphygmomanometers.

As sphygmomanometer account for virtually all the mercury measuring devices used for healthcare the assessment for sphygmomanometer represent the assessment of option a2.

Alternatives for reducing or preventing mercury in new products

Mercury-containing sphygmomanometers used for home/self assessment and in hospitals have to a large extent been replaced by electronic devices based on the oscillometric technique. Equipment based on the oscillometric technique is not suitable for blood pressure determination in all cases and the discussion of availability of alternatives therefore focus on alternative sphygmomanometers based on the auscultatory technique in which the mercury manometer has been replaced by an aneroid or an electronic manometer. See the detailed description of the equipment in section 2.5.1.4. A number of mercury-free sphygmomanometers have passed the test of the European Society for Hypertension and must be considered reliable for these measurements. The main restraint for the use of mercury-free devices has been that the mercury-free devices were less stable and needed more frequent calibration. Frequently means, as defined by an independent advisory group for the Medicines and Healthcare products Regulatory Agency in the UK (IAG 2005) annually or based on the manufacturer's recommendation. In Germany sphygmomanometers are recommended to be checked every second year. In Sweden where mercury sphygmomanometers have been totally phased out, all blood pressure measuring equipment is recommended to be checked once a year and calibrated when necessary. Many manufactures recommend to check the sphygmomanometers every second year or for aneroid non-shock-proved sphygmomanometers if the meter has been dropped.

The checking and calibration issue is further discussed in section 0.

6.5.2.1 Impacts on EU manufacturers and the market

Impact of prohibiting marketing of mercury sphygmomanometers

Mercury sphygmomanometers are manufactured by at least four manufacturers in the EU. All enterprises are small or medium sized enterprises. One of the companies is specialised in sphygmomanometers whereas the others are specialised in diagnostic instruments. Manufacture of mercury sphygmomanometers takes up a minor part of the total turnover of the enterprises and all enterprises also manufacture mercury-free sphygmomanometers. In total it is estimated that about 30-50 persons are employed in the manufacture of mercury sphygmomanometers in the EU. Production for the EU market account only for about 15% of the production of mercury sphygmomanometer; the remaining part being exported to countries outside the EU.

Beside these four manufactures, at least two manufacturers are manufacturing mercury-free sphygmomanometers for manual reading. These manufacturers would benefit from an increased market for mercury-free sphygmomanometers.

As mercury-free devices are already manufactured by the companies, the costs to the industry for switching to production of mercury-free alternatives are likely to be negligible.

A significant part of the mercury sphygmomanometers marketed in the EU is imported from Asia. According to a major EU manufacturer import account for a major part of the market in particular in countries without domestic production of sphygmomanometers. A prohibition of the marketing of mercury sphygmomanometers may result in a shift from imported mercury equipment to alternatives produced in the EU.

In summary, the impacts on the industry of a prohibition of the marketing of mercury sphygmomanometer are estimated to be insignificant.

Impact of prohibiting export of mercury sphygmomanometers

In total about 25-45 persons are employed in the manufacturing of mercury sphygmomanometers exported to EU-extra countries. A ban of the export of mercury sphygmomanometers would significantly impact the manufacturers. Some costumers, requesting EU produced equipment because it is considered more reliable and safer, may act in response to an EU ban, by requesting EU produced alternatives. Alternatively, the customers may act by requesting mercury equipment produced outside the EU. A manufacturer points a possible effect, that a shift to equipment produced outside the EU, may result in an increased risk of contamination of users and patients by breakage of less safe equipment.

6.5.2.2 Impacts on the users of the equipment and waste disposal

Costs to the users from purchase of equipment

The current number of mercury sphygmomanometers sold on the EU market is estimated at 30,000 - 60,000 units (see section 2.5.1.4). The mercury sphygmomanometers account for approximately 10% of the total market of sphygmomanometers. For 90% of the manual sphygmomanometers used in the EU the users have concluded that the advantages of replacing mercury sphygmomanometer outweigh the drawbacks of the alternatives as compared to mercury equipment.

According to the available information the main users of mercury sphygmomanometers are general practitioners, whereas hospitals in many Member States have more or less phased out mercury sphygmomanometers.

The price of alternatives varies by quality (see section 2.5.1.4)). The price difference between European produced alternatives and mercury sphygmomanometer varies from €0 (€60 for both types) for shock-proof conventional aneroid sphygmomanometer to approximately €100 (approximately €160 compared to €60 for the mercury sphygmomanometer) for high performance sphygmomanometers with electronic gauges.

The total extra costs to the users in the EU of purchasing alternatives can be estimated at €0-6,000,000 per year depending on which alternative is chosen.

Calibration of equipment

Mercury-free sphygmomanometers have traditionally been more vulnerable to shock than mercury sphygmomanometer and have needed more frequent calibration and this is often emphasized in the discussion about phasing out mercury sphygmomanometers.

First of all it should be noted that mercury sphygmomanometers also need proper regular calibration and have to be operated by trained personnel. Markandu *et al.* (2000) noted in a paper in Journal of Human Hypertension after examinating 500 mercury sphygmomanometers and their associated cuffs at a large London teaching hospital: "*More than half had serious problems that would have rendered them inaccurate in measuring blood pressure. At the same time, assessment of the technical knowledge needed to measure blood pressure by the auscultatory technique was also carried out amongst medical and nursing staff. This showed a considerable level of ignorance. These results inevitably lead to inaccurate measurement of blood pressure with serious consequences.*"

Knight at al. (2001) found in a survey of a total of 472 sphygmomanometers (of these 75.4% mercury) in general practices in the UK that 69.1% of mercury and 95.7% of aneroid instruments checked had no service records. A large proportion of mercury sphygmomanometers tested had deficiencies likely to affect the reading following the recommended measurement technique. Only two-thirds were accurate at all pressure levels tested. Only 38.8% of aneroid instruments were accurate at all test pressure levels.

Another research study in 2001 assessed the accuracy of mercury and aneroid sphygmomanometers in use in 231 English general practices (Rouse and Marshall 2001). Of 949 mercury and 513 aneroid sphygmomanometers, 9.2% gave readings that were more than 5 mm Hg inaccurate (it was not indicated how many of these were mercury and how many aneroid sphygmomanometers). Nearly 100 sphygmomanometers were in such a poor physical state, for instance they had air leaks or dirt in the mercury, that the tester suggested they be withdrawn from service. No practice had arrangements for maintenance and calibration of sphygmomanometers. Nationally, one of 54 practices had an arrangement for maintenance and calibration, whereas 34 of the 54 practices accepted calibration by drug companies on an irregular basis, and 19 had no service or had not calibrated their sphygmomanometers for years.

In response to the request for less vulnerable and more accurate mercury-free sphygmomanometers several manufactures have in recent years developed more shock-proof sphygmomanometers as mentioned in section 2.5.1.4 regarding alternatives. Assessments of alternatives just a few years old may not take into account the development of this equipment.

One of the questions that have been raised is whether mercury sphygmomanometer would still be needed for calibration of the mercury-free equipment in hospitals and clinics. In order to throw light on this question, the recommended calibration procedures from two of the manufacturers, Welch Allyn and AC Cossor & Son (Surgical) Ltd, is briefly reviewed.

The Welch Allyn DuraShock is a shock resistant aneroid sphygmomanometer with a accuracy of +/-3 mm Hg similar to a Hg sphygmomanometer. The product line has four models of varying quality and price The calibration warranty of the equipment range from 5 years for the cheapest "bronze" to lifetime for the most expensive "platinum" model. (Welch Allyn 2008b). Similar equipment will also be available from the German manufacturer Riester during autumn 2008.

In spite of the calibration warranty the manufacturer recommend to make a full check of calibration at least every two year, but the equipment has also a feature for a quick check of the calibration. Regarding the equipment used for a full check calibration the manufacturer states:

"Note: Your ability to measure the accuracy of a gauge depends upon the sensitivity of the pressure standard you use for the calibration procedure. If using a manometer (mercury column or aneroid gauge) rated at ± 3.0 mm Hg, an undetectable error of up to 6.0 mm Hg is possible. If using a device (e.g., digital pressure standard) rated at ± 0.1 mm Hg, an undetectable error of up to only 3.1 mm Hg is possible.

"Welch Allyn recommends using as sensitive as possible a pressure standard when performing calibration checks. A Setra Pressure Meter (part no. 2270-01), which is calibrated for ± 0.1 mm Hg, or Netech (part no. 200-2000IN), which is calibrated for ± 1.0 mm Hg, works well for this application." (Welch Allyn 2008a)

The manufacturers do not recommend a mercury manometer for the calibration because of its inaccuracy, but instead a digital manometer. Both the Setra Pressure Meter and the Netech meter are digital pressure gauges. The Digimano 1000 from Netech is marketed as ideal for calibrating sphygmomanometers and is provided with a "blood measure calibration kit" (Netech 2008). The meter has an accuracy of 0.25%. It should be mentioned that for calibrating the manometer of the sphygmomanometer, what you need is an accurate pressure gauge. This gauge may not be different from pressure gauges used for other purposes of measuring pressure in the relevant pressure range.

The Greenlight 300 sphygmomanometer from AC Cossor & Son (Surgical) Ltd, UK is an electronic device that has been developed in order to provide a sphygmomanometer that can also be used for calibration of other meters.

According to the manufacturer "D*ue to its reliable accuracy, the greenlight 300 is suitable for use as a reference manometer for checking the calibration of aneroid and mercury sphygmoma-*

nometers" (Accoson 2008). The Greenlight 300 can be ordered for use as a reference manometer supplied with a Y-piece tubing set that allows an air reservoir to be connected to both the Greenlight 300 and the sphygmomanometer that is under test and a calibration certificate traceable to international standards.

The UK Medical Devices Directive requires measuring devices to be checked every year (aneroid devices need to be checked every six months). The specification of the Greenlight is that taking into account the worst case tolerance of all components and the range of environmental conditions, only 1 in 10,000 devices would need any form of recalibration each year (Accoson 2008). Pressure Cycle Test showed that the maximum indicated error both during the test and after 10,000 pressure cycles was +/- 0.8 mmHg, confirming compliance with both European and American standards which specify a maximum error of +/- 3 mmHg.

The Greenlight 300 will automatically self-calibrate to zero each time it is switched on ensuring reliable accuracy. The calibration of the Greenlight 300 need according to the manufacturer only be checked after four years. Other components such as the air control valve, cuff and tubing should be examined regularly for signs of wear. This will ensure continuing measurement accuracy. In the event that the Greenlight 300 fails to zero on switch on, the over-pressure orange LED will display. If this occurs the device should be checked by an authorized service centre.

A Swedish evaluation of mercury-free measuring devices conclude regarding the experience with use of mercury-free equipment :"*All blood pressure measuring equipment is recommended to be checked once a year and calibrated when necessary. There is no evidence that the need for checks and calibrations cause practical problems or diagnostic problems. There are no reports of problems or inconveniences related to the change in routines"*.

The available information clearly indicates that electronic pressure gauges, kept solely for calibration of sphygmomanometers, are more accurate than traditional mercury sphygmomanometer. The only impact would be that the electronic devices are more expensive than a mercury sphygmomanometer.

As demonstrated in several surveys until recently many sphygmomanometers has not been tested regularly, but there seems to be an increased awareness about the need for regularly calibration. More and more hospitals use quality management systems (e.g. ISO 10001) and it is an integrated part of the management system to regularly calibrate all equipment.

Several guidelines recommend that sphygmomanometer are calibrated every year or as specified by manufacturers. The UK Medical Devices Directive e.g. requires measuring devices to be checked every year whereas aneroid devices need to be checked every six months. This applies to conventional aneroid and not the newest types. The manufacturer of Greenlight 300 proposes to check the calibration after 4 years. Instructions for Welch Allyn Durashock indicate that the equipment should be calibrated at least every two years.

The calibration is in hospitals often undertaken by the technical department whereas the calibration of equipment in general practices are done by specialised companies or, as is the case in the UK, by drug companies, providing this service for free as part of their customer service.

The costs of calibration undertaken by a service company in the UK is approximately 25£ (32 €). With shipment the total costs would be approximately 40 €. The price is approximately the same in Denmark. It should be noted that this is nearly the same price as a new aneroid sphygmomanometer of the cheapest type. For technical departments in hospital, undertaking calibration of all equipment in the hospital, the costs may be lower.

For cheap aneroid sphygmomanometer, that are not shock-resistant, the costs of calibration would over the life of the meter exceed the costs of he meter by many time if the equipment should be calibrated every half year.

For the cost assessment, it is assumed that the calibration frequency of shock resistant aneroid sphygmomanometer, mercury sphygmomanometer and sphygmomanometer with electronic pressure gauges is the same, but dependent on the actual prescribed frequency in each country or institution.

Cost of batteries
In the case of electronic equipment, the sphygmomanometer needs batteries. According to a manufacturer of one type of electronic sphygmomanometer, the equipment uses 4 AA alkaline cells that are typically changed every year (after the equivalent of 170 hours continuous use). The cost is roughly estimated at €3 per year.

6.5.3 Thermometers

The following section includes a description of the impacts on manufacturers and users of thermometers. Other impacts and a conclusion is provided later in section 0 and 0 which common for all the measuring equipment.

Medical thermometers are already covered by Council Directive 76/769/EEC and option a2 would consequently have no impact on manufacturers or users of thermometers.

Alternatives for preventing mercury in new products
Alternatives to mercury thermometers are reviewed in section 2.5.1.1. Suitable alternatives to mercury thermometers do not exist for all tests undertaken in accordance with standards, but the experience from Member States with a prohibition of mercury thermometers for other applications demonstrate that alternative solutions exists.

It is generally accepted that alternatives exist to all remaining uses of mercury-in-metal thermometers and mercury-in-glass thermometers at measuring resolution of 1°C and below 200°C.

For temperature measurements above 200°C at a resolution of 1°C, dial thermometers with coiled bimetal or a liquid or air filled metal cylinder with a dial for manual reading are available. For measurements at 0.1°C or better resolution the alternatives are electronic thermometers. See more details on the applicability of alternatives in the following section.

6.5.3.1 Impacts on EU manufacturers and the market

Impact of prohibiting marketing of mercury thermometers
Mercury thermometers are manufactured by at least 11 manufacturers in the EU. Besides these some manufacturers of small volumes may exist. All identified manufacturers also market electronic alternatives, but the electronic equipment is to a high extent manufactured outside the EU.

All manufacturers are small or medium sized enterprises. According to German manufacturers of mercury thermometers about 400 people are employed in the manufacturing of mercury thermometers in Germany. Extrapolated to the EU some 1000-1500 people may be employed in this industry. About half are employed in the manufacture of thermometers for EU extra export.

Some of the enterprises are specialised in the manufacturing of thermometers for laboratories, others for thermometers for industry and marine applications whereas a number of companies manufacture for both markets. A restriction of the use of thermometers as defined above would in particularly impact the manufacturers specialised in the production of thermometers for industrial and marine applications.

It is roughly estimated that a restriction in line with Directive 76/769/EEC would imply a reduction in the use of mercury for these thermometers of about 1/3 of current use in the EU (1/6 of current production) and would consequently have an impact of the employment of 170-250 people.

The restriction would increase the sale of electronic equipment, which to some extent is supplied by the same companies, but this equipment is also to a large extent produced and marketed by manufactures specialised in electronic equipment and a significant part of the electronic thermometers are produced outside the EU. Several small and medium sized enterprises manufacture electronic thermometers within the EU. As the electronic equipment for high precision measurements are more expensive than the mercury thermometers the positive impact on the manufacturers of electronic thermometers may outweigh the negative impact of the mercury restriction, in spite of the fact that a substantial part of the equipment is produced outside the EU.

A restriction of the export of thermometers for non-analysis applications would have an impact of the same magnitude, but would probably not result in a positive impact of manufacturers of electronic equipment.

6.5.3.2 Impacts on the users of the equipment

Costs to the users from purchase of equipment

Current applications of mercury thermometers that fall outside the exemptions for analysis purposed would among others be applications for process control in pharmaceutical and food industry, incubating and breeding (e.g. of game) and temperature measurement of engines (in particularly diesel engines on ships).

The main reason for using mercury in the thermometers is either the need for measurements at a resolution of 0.1°C or better (e.g. in incubators), or the need for measuring at higher temperatures. For some product lines, e.g. the V-line Industrial Thermometer from Brannan and Sons Ltd. (UK), thermometers for measurements below 200°C are filled with spirit while thermometers for >200°C are mercury filled. From some manufactures thermometers also using mercury in the lower temperature range are available.

In many cases the mercury thermometers are used as backup and check of electronic thermometers. One of the main uses of the thermometers is for engines of ships. For this application a major manufacturer has indicated that alternatives are available and applied in new engines, but mercury thermometers are requested for replacement of broken thermometers.

From countries in which thermometers for these purposes have been prohibited for years it is known that the thermometers can be substituted. For some applications (e.g. diesel engines of ships) it may be quite costly to replace a broken thermometer with thermometers of other types, and in particular companies in the marine industry may in practice solve the problem by purchasing the thermometers directly outside the country.

For some products marketed, with a resolution at 1°C and measurements below 200°C there would obviously be alternatives available and these thermometers could be substituted without higher costs to the user. The same is the situation for the remaining uses of mercury in other thermometers than glass thermometers.

For temperature measurements above 200°C dial thermometers are according to Danish suppliers available at prices of 2-4 times a similar mercury thermometer. The price on the Danish market of a mercury-free diesel engine thermometer is approximately €50.

When comparing the prices it is necessary to distinguish between new equipment and mercury-in-glass thermometers used for replacement of existing equipment. An industrial thermometer would typically consist of a casing, a glass insert (the thermometer) and an immersion tube. If the glass insert break it can be replaced, without changing the casing and immersion tube at a much lower price than replacing the entire thermometer. In this case the price of replacing the whole thermometer with an alternative may be more than 2-4 higher than the price of replacing the glass insert.

For measurements at 0.1°C or better resolution the alternatives are electronic thermometers with a price of approximately 10 times the price of a mercury thermometer. A common concern with the electronic equipment is the drift and the fact that it is not apparent when the reading is not correct. The problem may be overcome by using two electronic sensors that continuously check whether they read the same temperature, but it is a rather expensive solution.

It is difficult to estimate the exact number of thermometers that should be substituted. Based on information from German manufacturers it is estimated that mercury thermometers on average contain 3 g mercury and the EU consumption of 0.6-1.2 tonnes mercury correspond to 200,000 - 400,000 thermometers. Half of these are used for laboratories and a significant part of the remaining is used for some industrial applications where the analysis are done in accordance with some standards. Some are thermometers for which alternatives are readily available at similar prices.

It is roughly estimated that 50,000 - 100,000 thermometers could be substituted. For a few of these the substitution costs would be quite high because electronic equipment would be needed, but for most of the equipment the price of alternatives is estimated to be 2-4 times higher. Considering the uncertainty on an average price of the thermometers it is estimated that the extra average price would be €15-60 per thermometer. For some applications the price may be significantly higher.

The total costs to the users would under these assumptions be €750,000-6,000,000 per year, corresponding to €5,000 - 20,000 per kg mercury substituted.

Thermometer measurements in accordance with standards

With the definition of the scope of the restriction to include only thermometers for temperature measurements not done in accordance with analysis standards, the question regarding standards are not an issue.

For a general ban of mercury thermometers there would be a need for changing a wide range of standards. Some of the main standards prescribing the use of mercury thermometers are standards from ASTM (USA by widely applied in Europe), IP and BS (UK) and DIN (Germany).

The number of standards and corresponding thermometers are quite high. As an example, a list of nearly 100 different IP thermometers and the corresponding IP and ASTM standards are available at the website of the UK manufacturer Brannan at http://www.brannan.co.uk/products/lab_ip.html. The thermometers listed are made in accordance with specifications for use with specific test methods of petroleum and its products. Similarly a wide range DIN standards prescribe the use of specific mercury thermometers. Changing the mercury thermometer with other thermometers is not straight forward as the temperature measurement is also an effect of the interaction between the medium and the thermometer.

The American ASTM has started the process of developing alternative standards for mercury-free liquid-in-glass thermometers and electronic thermometers. The ASTM E2251 - 07 "*Standard Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids"*. This standard was created to introduce and give specifications for liquid-in-glass thermometers using low-hazard precision thermometric liquid alternatives to the mercury, mercury thallium and toluene/organic filled (spirit) thermometers found in Specification E 1. Besides developing the new standard it is also necessary to change all the analysis standards that make reference to the standard for the equipment. The thermometers in this standard will meet the tolerances, repeatability and response times necessary for use in ASTM standards when used following the manufacturer's instructions. In section 2.5.1.1 is mentioned a new thermometer line meeting the requirements of this standard for a part of the temperature range of mercury thermometers. Similar standards have to the knowledge of the authors not been developed by e.g. BS or DIN.

The application of electronic thermometers as alternatives to ASTM liquid-in-glass thermometers has been reviewed by Ripple and Strouse (2005) as a part of the ongoing work in ASTM for development of new standards. Replacing a liquid-in-glass thermometer with a electronic thermometer when using a standard is not straight forward, but the paper suggest some guidelines for the specification and application of alternatives. The authors conclude that the approach outlined allow the replacement of a liquid-in-glass thermometer with an alternative offering a high degree of confidence that the replacement equals the performance of the liquid-in-glass thermometer in all important respects. However, clearly alternatives are not available and applicable for al measurement done in accordance with ASTM standards.

Check and calibration of equipment
Electronic thermometers have the drawback that they may be subject to drift and it may be necessary to check - and calibrate if necessary - the equipment more often than mercury thermometers.

Costs of batteries
In the case of electronic equipment, the thermometer need an electricity source which may often be a battery. The need for battery varies with the type and the use of the thermometer. The costs is roughly estimated at €2-6 per year.

6.5.4 Barometers

The following section includes a description of the impacts on manufacturers and users of thermometers. Other impacts and conclusions are provided later in section 0 and 0 together with all the measuring equipment.

Barometers may in principle be applied in hospitals, but as alternatives are readily available, it is estimated that the marketing of mercury barometers for hospitals is insignificant and probably not existing at all.

Alternatives for reducing or preventing mercury in new products
A number of alternatives to mercury barometers are marketed. For the professional market alternatives are mainly electronic devices which are as precise as mercury barometers. No specific applications for which mercury barometers cannot be replaced have been identified.

6.5.4.1 Impacts on EU manufacturers and the market

Impact of prohibiting marketing of mercury barometers

Mercury barometers are manufactured by at least five manufacturers in the EU, but most of the manufacturers mainly produce barometers for the consumer market. All enterprises are small or medium sized enterprises. The same manufacturers also manufacture mercury-free aneroid barometers for the domestic market. For this market the main function of the barometer is being a piece of furniture and aneroid barometers are adequately precise. To allow the manufacturers to adapt their business in line with the restrictions and move over to the production of mercury-free barometers, an additional phasing-out period is provided in Directive 2007/51/EC.

At least one, and possible a few, of the manufacturers also produce mercury barometers for the professional market. The market is very small and decreasing and it is roughly estimates that not more than 2-20 are full time employed in the manufacture of barometers for the EU market.

Impact of prohibiting export of mercury barometers

In total about 2-20 persons are employed in the manufacturing of mercury barometers exported to EU-extra countries.

6.5.4.2 Impacts on the users of the equipment

Mercury barometers are used to some extent in weather stations, meteorological departments, airports and airfields, wind tunnels, oil refineries, engine manufacturing, sport sites, offshore installations (e.g. windmill parks) and on ships. It has not been possible to identify any specific uses of mercury barometers, for which mercury barometers is still the main choice. The main reason for using mercury barometers is based on tradition and the property that it is immediately apparent when the equipment does not work properly. Some customers regard electronic instruments as “black boxes”, where it is difficult the see whether they function correctly.

According to the Guide to Meteorological Instruments and Methods of Observation from World Meteorological Organisation (WMO 2006) there is an increasing move away from the use of mercury barometers for the reasons that mercury vapour is highly toxic, free mercury is corrosive of the aluminium alloys used in the airframe, special lead glass is required for the tube, the barometers are very delicate and difficult to transport, it is difficult to provide maintenance of the instrument and for cleaning the mercury, the instruments must be read and corrections applied manually, and other pressure sensors of equivalent accuracy and stability with electronic read-out are now commonly available.

The alternatives have many advantage compared to the mercury instruments, as mentioned by WMO, and this has been driving the market away from mercury barometers.

Costs to the users from purchase of equipment

A comparison of price of mercury barometers with other barometers is complicated by the fact that the barometers also serve as a household feature, the price therefore are more likely to vary according to the design feature. Mercury barometers are available for prices in the range of € 100-1000 and alternatives are available in the same price range. Electronic precision barometers based on vibrating element sensors are also available at higher prices, but this equipment has features not making it directly comparable to mercury instruments. Floyd et al. (2002) report that the price of mercury barometers generally is higher than the price of electronic barometers.

The price of the mercury barometers or alternatives seems not to be a main factor when choosing the barometers and has not been assessed further. It is roughly estimated that changing to alternatives would not increase the costs to the users.

Calibration of equipment
The WMO guide specify that both electronic and mercury barometers should be calibrated frequently.

6.5.5 Cost of spill and waste disposal

If not cleaned up immediately, the costs of spill of mercury from a broken sphygmomanometer, barometer or thermometer may be quite high. Because of the high mercury content and the use in hospitals, costs of spill of a sphygmomanometer in a hospital setting may in particularly be high and the following sections focus on broken sphygmomanometers.

The response to the spill may range from simply removing the visible mercury and clean the floor, to clearing the room for a period of time and hiring a specialised company for a full cleaning of the room. In general, the true costs of mercury spills are not well documented and tend to be anecdotal. The number of breakages is not known, the clean-up costs probably vary greatly from country to country and from institutions to institutions, and no overview data of cleaning costs in hospitals in Member States have been available.

From the USA, the Sustainable Hospitals Project (2003) provides and some examples on costs of spill clean up reported from US universities and hospitals. Some selected examples are shown in Table 6-7 please see the original document for more examples and details.

The examples indicate the costs if the rooms or buildings are to be properly decontaminated in order to avoid exposure to the personal and patient. It has not been possible to find case stories from European hospitals, but the potential high costs of cleaning have certainly limited the used of mercury sphygmomanometer in hospitals.

Table 6-7 Examples of costs of cleaning up after mercury spills (selected examples from Sustainable Hospitals Project 2003)

Example	Clean-up costs (USD)
Three oral fever thermometers - clean up of room and discarding all carpeting	5,000
Broken sphygmomanometer	5,000
Broken barometer in Medical Centre	Outside Vendor Cleanup Company – Time, Materials and Labour: $4,094 Replacement of Mercury Spill Vacuum: $3,200 Medical Follow up (Blood Testing) For Hospital Staff: $260 Mercury Disposal Costs: (Will Vary Per Vendor Used) $1,600 Labour Hours Cost for Hospital Personnel Involved Est.: $1,000 Total Costs for Spill Mitigation: $10,054.00
Dispose of a lab oven contaminated by a broken mercury thermometer	5000
Clean up after sink trap work	570,000
Clean up contamination and restore building to original condition	350,000

In many instances the response to spill would rather be to clean up using an absorbent and ventilate the room well.

The UK Department of Health Safety Information Bulletin SIB(88)14 describes the manner in which mercury spillages should be dealt with in hospitals in the UK (as cited by Mercury Safety Products 2008):

1. Combine the droplets of mercury if possible
2. Pick up as much mercury as you can using a syringe
3. Apply an absorbent to the affected area
4. Contain the waste mercury in a well labelled, lidded plastic container
5. Ventilate the room well
6. Waste mercury should be sent for reclaiming or disposal as toxic waste

It is assumed that similar procedures are applied in most Member States. For the purpose of cleaning up spills, mercury spill kits are available.

Instead of estimating the possible costs of cleaning up, which implies that the actual number of accidents and the clean-up costs are known, an alternative approach is selected where the costs of having adequate spill response equipment is taken as the best estimate. In fact, to these costs should be added the costs of applying the kits, but it is assumed that sphygmomanometer spills are quite seldom.

Mercury spill equipment is e.g. supplied in the UK by Mercury Safety Products Ltd., which will be used as case. According to the company the primary consideration in dealing with mercury spillages is restricting the spread of the spillage. In practice, this relates directly to the speed of access to a spillage kit. Delays in dealing with the spillage result in people walking through the affected area and spreading the contamination even further (Mercury Safety Product 2008). For this reason, spillage kits are best sited close to the likely incident areas. According to a major supplier of spillage kits they recommend that only one spill kit is required per building or per institution, as long as staff have undergone adequate training including knowledge of the location of the spill kit. General practitioners usually buy one or two spillage kits per medical centre.

The price of a mercury spill kits for hospital use is about €25-35, dependent on the numbers purchased. For a general practitioner, only purchasing a few kits, the price would be around €35. Each kit can be used four or five times and has a shelf life of about four years (Mercury Safety Product 2008). The shelf life of the kit is consequently shorter than the expected life of the mercury sphygmomanometer.

It is for the cost assessment roughly assumed that one spill kit is needed for each or every second mercury sphygmomanometer in order to prevent even higher costs in case of breakage of mercury sphygmomanometer without fast spill response.

The response to a spill of mercury from a thermometer in a laboratory or in the industry would probably be to remove the visible mercury, apply an absorbent and clean the floor. The extent of the spill is highly dependent on whether it is the capillary (less than one gramme) or the bulb (several gramme) that brakes. The number of breakages is not known, but most likely most thermometers are taken out of service because they brake.

In many cases the mercury is probably just removed mechanically, but a proper response would be to apply a mercury spill kit as described above, dependent on the numbers purchased. Each kit can be used four or five times and has a shelf life of about four years (Mercury Safety Product 2008). On this basis the costs of spill response is roughly estimated at €5-20 per thermometer. The actual costs of the man-power for cleaning up the spill may quite well be more than the price of the spill kit, but these costs have not been estimated.

Costs of treatment of Hg waste
Mercury thermometers and the manometer part of discarded mercury sphygmomanometers and barometers are hazardous waste and shall be disposed accordingly, although the equipment in many instances may be disposed of with the municipal solid waste. The disposal implies a system for collection and temporary storage of the mercury waste and an agreement with a contractor for collection and further treatment of the waste. Measuring equipment from general practices and small enterprises may in some Member States be disposed via municipal collection systems for hazardous waste.

Electronic alternatives to the measuring equipment shall as well be collected separately and disposed off as electronic waste. Aneroid sphygmomanometers, barometers and mercury-free mechanical thermometers may be disposed of as general waste, but should preferably, due to the metal content, be disposed off for metal recycling.

According to a Dutch recycling company the recycling costs of waste of mercury-containing measuring equipment is approximately €4 per kg waste. With an average mercury content of 3%, the cost per kg of mercury corresponds to €130 per kg Hg. These costs, however, only represent the last step in the waste treatment.

The measuring equipment is usually managed with other waste fractions and it has been beyond the limits of this study to quantify the cost differences between the different disposal methods. A major part of the costs would be the time consumption for collection and temporary storage of the equipment, and the differences in costs of disposal are considered to be small compared to other cost elements.

6.5.6 Costs to society from impacts on human health and the environment

Although a significant quantity of measuring devices are sent for recycling, part of the mercury is released to the environment during different steps of the life cycle of the equipment. Through the manufacturing process, through breakage, during disposal (e.g. in hospital incinerators or MSW incinerators) and during recycling of the equipment.

It is beyond the current study to undertake a detailed study of the costs of impacts on human health and the environment of mercury released in connection with the use of mercury measuring devices.

To have a first impression of the magnitude of the benefits of reducing mercury releases, it is assumed that only 10% of the mercury is released to the atmosphere from the entire life cycle of a measuring device. If using the estimates of Rice and Hammit (2005), the health benefits of reducing the marketing of one kg mercury would be €4,000 - 110,000 per kg (see section 6.3), which may be compared to the costs of substituting mercury.

The health benefit of reducing mercury emissions by 330 - 710 kg (10% of the reduced consumption by option a1 per year) would be €1.3 - 77 million per year. For option a2 the equivalent benefits could be €1.2 – 66 million per year.

The large range of uncertainty around these estimates does not permit any clear conclusions, but when compared to the cost ranges for substituting to mercury-free equipment, it can be seen that the health benefits for sphygmomanometers are likely to be higher than the costs to users, whereas for thermometers the simple health benefits are not as compelling, although considering the probability of higher than 10% mercury releases, and combined with environmental and other benefits, thermometers should also be seriously considered.

6.5.7 Conclusions

Costs to the users of sphygmomanometers

The costs to users over a five-year period is estimated below for the mercury sphygmomanometer, a shock-proof aneroid sphygmomanometer of the same price and a high-end electronic sphygmomanometer (.

Table 6-8). It is quite clear that the estimate of the total cost is very sensitive to the assumptions regarding calibration, as the costs of calibration, if undertaken by a service company over a 5-year period, for some of the equipment greatly increase the price of the equipment.

Table 6-8 Estimated costs to users in general practice over a five-year period

	€ per piece of equipment		
	Mercury sphygmo-manometer	Shock resistant an-eroid sphygmoma-nometer	Electronic sphygmomanometer
Purchase	60	60	160
Calibration costs *2	100-200	100-200	100-200
Spill response	17-35	0	0
Batteries			15
Waste collection and disposal *1	n.a.	n.a.	n.a.
Total	177-295	160-260	285-385
Difference compared to mercury (average)	0	-26	99
Difference, €/kg Hg (average) *3	0	-305	1,164
Difference at EU level - 45,000 pieces of equipment, € per year (average)	0	-1.2 million	4.5 million

*1 It is assumed that all types have to be separately collected for recycling and the costs differences are consequently limited.

*2 According to manufacturers the equipment need calibration every second to fourth year, but in many hospitals and general practices it may be required in any case to calibrate the equipment every or every second year. It is assumed that the equipment is calibrated by a service company either every year or every second year.

*3 Assuming that the mercury content per meter is 85 g (UK average).

The impacts on the manufacturers of sphygmomanometer in the EU of a marketing ban are estimated to be insignificant as all manufacturers of mercury sphygmomanometer also manufacture alternatives.

The main constraints by general practitioners for replacing mercury sphygmomanometers with alternatives is that mercury sphygmomanometers by tradition have been considered more reliable and many general practitioners are reluctant to change the well-known equipment with new types of equipment. This reluctance is sustained by the fact that the international or national societies on hypertension still mention mercury sphygmomanometer as the “gold standard”, although the term is today often put in quotation marks. There is a need for clear statements distinguishing between the different types of alternatives, e.g. equipment tested in accordance with the international protocols and more unreliable equipment.

In some specialised cardiological departments it may be relevant using the mercury equipment in some research programmes in order to ensure that obtained data are comparable to previous studies, but this application will be covered by the general exemption in Council Directive 76/769/EEC.

Costs to the users of thermometers
Compared to the sphygmomanometer, as assessment of thermometers are complicated due to the fact that a wide range of thermometers are used for a range of applications. It is most likely that an extension of the ban on liquid mercury in measuring devices would include industrial mercury-in-glass thermometers measuring at 1°C resolution, but a more detailed assessment would be necessary to identify the applications of thermometers of higher resolution that would be impacted, as all measurements in accordance with standards would be exempted. For the higher resolution applications the alternatives are typically ten times the price of mercury thermometers, but the alternatives have more features than the mercury thermometers.

For this reason only an indicative estimation for the industrial thermometers is provided. It is roughly estimated that 50,000 - 100,000 thermometers should be substituted. Considering the uncertainty on an average price of the thermometers it is estimated that the extra price would be €15-60 per thermometer. The total costs to the users in the EU would under these assumptions be €750,000-6,000,000 per year, corresponding to €5,000 - 20,000 per kg mercury substituted.

The estimate clearly indicates that the costs of substitution one kg of mercury in thermometers is significantly higher than substituting mercury in sphygmomanometer even when the sphygmomanometers are substituted with the most expensive electronic equipment.

Cost to the users of barometers
The impact of ban on the marketing of liquid mercury in measuring devices in 76/769/EEC is estimated to have a very limited impact of both manufactures and the users of barometers. The use of mercury barometers for professional applications has more or less already been phased out due to the advantages of the alternatives.

The estimate of the costs to the users of prohibiting mercury is complicated by the fact that the price of the mercury barometers is not only determined by the technical properties of the barometers but also the design, and mercury barometers seems not to be demanded because of lower price of the mercury instruments compared to alternatives.

It is therefore estimated that the prohibition of mercury barometers for professional use would not have any significant cost impact on the users.

Benefits of reduced environmental and health impact
Benefits of reduced environmental and health impact can on the basis of existing investigation only be estimated at very high uncertainty. The simple health benefit of reducing the marketing of one kg mercury has been estimated to be in the order of €400-11,000 under the assumption that only 10% of the mercury in the equipment is released to the air during the entire life cycle. The actual amount released, including long-term releases from landfills and deposits, would not only be significantly higher, but environmental and other benefits would also contribute considerably.

General ban of export of liquid mercury in measuring devices
A general ban of export of mercury would impact the manufacturers of mercury measuring equipment in the EU. It is estimated that 30-50 employees in small and medium sized companies are employed in the manufacturing of mercury sphygmomanometer for EU-extra export, 170-250 people for mercury thermometer export and 2-20 for barometer export. As European brands by some customers are requested because they are considered more reliable, a general export ban may also increase the request for European produced alternatives, having a positive impact on EU manufacturers of alternatives. However, the increased request for alternatives may most likely not fully outweigh the reduced export of the mercury equipment.

6.6 Mercury catalysts for polyurethane elastomer production

Mercury catalysts are used for manufacturing of some types of polyurethane (PU) elastomers. On a global scale it is estimated that mercury catalysts are used for less than 5% of the production and it is estimated that 20-35 tonnes of mercury is used for PU elastomer production in the EU. The mercury of the catalysts remains in the final products and the total mercury content of PU elastomer marketed in the EU is estimated to be of the same magnitude as the amounts used for the production. Nearly 100% of the mercury in PU elastomers ends up in the municipal solid waste stream in landfills or waste incinerators, and may significantly contribute to the atmospheric mercury releases from municipal solid waste incineration.

A number of alternatives to the mercury catalysts exists and these substitutes are today used for over 95% of PU elastomer systems, and have been in use for many year. In fact, known mercury-free catalysts could be used for nearly all elastomer applications, but some reduction in the key performance characteristics of activity, selectivity, catalyst lifetime, etc., may have to be accommodated until the best system is identified for a given application.. Industry sources have confirmed that virtually all remaining PU elastomer systems could also be cured with mercury-free catalysts – given enough time and incentive to identify the most appropriate catalyst.

Current community level legislation and other measures
A number of pieces of European community legislation deal directly or (more often) indirectly with mercury catalysts and PU elastomers that contain them.

Directive 2002/95/EC of the European parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) (OJ L 37, 13.2.2003) restricts to less than 0.1% by weight the mercury content of any "homogeneously mixed" electrical or electronic part. Among other parts, mercury-catalysed PU elastomers have often been used to cast non-skid pads or "feet" supporting a range of electrical and electronic equipment.

Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles (OJ L 269, 21.10.2000) requires that no vehicle parts contain mercury. This could be relevant for PU elastomer parts used in bumpers, shock absorbers, steering wheels, etc.

According to Commission Decision (2000/532/EC) of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Directive 75/442 on waste and Council Decision 94/904 establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689EEC on hazardous waste (OJ L226/3, 6.9.2000) (as amended), end-of-life PU elastomers (typically containing at least 0.1% Hg by weight) could be defined as hazardous waste.

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (OJ L 182, 16.7.99), and Council Decision 2003/33/EC of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC (OJ L 11, 16.1.2003) restrict the mercury content of wastes that may be accepted at municipal landfill sites.

Regulation (EC) No. 304/2003 of the European Parliament and of the Council of 28 January 2003 concerning the export and import of dangerous chemicals (OJ L 63, 6.3.2003) requires exports from the EU of mercury compounds such as mercury catalysts to be registered, even when shipped as one part of a two-part PU elastomer system.

Council Directive 67/548/EEC of 27 June 1967 on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances (OJ B 196, 16.8.67) as amended by Commission Directive 2001/59/EC of 6 August 2001 (OJ L 225, 21.8.2001) requires organic mercury compounds and mixtures containing organic mercury compounds to be properly labelled.

Legislation beyond EU legislation in force in Member States, Norway or Switzerland
Legislation in Sweden, Denmark, Norway and the Netherlands goes beyond Community level legislation to restrict or ban the marketing of products or components containing intentionally added mercury, with a number of exemptions.

Norwegian legislation, from 1 January 2008, placed a general prohibition on production, import, export, sale and use of mercury and mercury compounds, which clearly includes PU elastomers containing Hg catalysts.

The Danish prohibition on import, export and sale of mercury and mercury-containing products exempts mercury-containing chemicals for “special applications,” including an exemption for catalysts.

The general prohibition in the Netherlands on marketing and use of mercury in products does not exempt mercury use in PU elastomers.

While Sweden has a prohibition on the production, sale and export of a variety of mercury-containing equipment, and has proposed a general ban for the future, it does not presently prohibit mercury compounds in PU elastomers.

6.6.1 Main options for preventing mercury in new products from entering the market

Policy options for reducing mercury use in PU elastomers are listed in Table 6-9. Economic incentives and self-regulation are not considered relevant options for this product group, for the reasons mentioned in the table.

Table 6-9 Policy options for reducing mercury use in PU elastomers

	Option		Effect on mercury in new products
Community legislation	a1	Fast phase-out of marketing and use of mercury or mercury compounds mixed with any kind of polymer or plastic	Reduce diffuse inputs of mercury to society by 16-28 tonnes per year in the near term (2-3 years).
	a2	Slow phase-out of marketing and use of mercury or mercury compounds mixed with any kind of polymer or plastic	Reduce diffuse inputs of mercury to society by 20-35 tonnes per year in the near to medium term (3-5 years).
	a3	No legislation	Increasing awareness of mercury in the EU is encouraging a gradual trend toward mercury-free catalysts; however, this trend is offset by the ease of using mercury in new applications of PU elastomer systems, as well as increasing imports from countries outside the EU.
Self-regulation	b1	Industry agreed phase-out	Difficult to capture imports, creating an unlevel playing field; even within the EU, this is a diverse industry with no common spokesperson or association
	b2	Reporting requirements	Impossible to specify firm objectives regarding reduced mercury use; perhaps useful in combination with other measures
Economic incentives	c1	Support research for substitutes	Impossible to specify firm objectives regarding reduced mercury use; perhaps useful in combination with other measures
	c2	Impose user fee on Hg catalysts	Politically difficult; No guarantee of significantly reduced mercury use since catalysts are less than 10% of the cost of the system.

6.6.1.1 Policy options selected for further analysis

The key policy options that should be further explored – a1 and a2 – both concern a phase-out of the use of mercury in PU elastomers.

There is a trade-off between options a1 and a2 in Table 6-9. According to industry information, if the phase-out in option a1 were to take place over 2-3 years, this option could quickly capture probably 80% of catalyst use, for which alternatives are rather easily available, and more during the following years. If the phase-out, as in option a2, were to be implemented over 3-5 years, one could be reasonably sure that at the end of that period virtually 100% of the mercury catalyst use could be replaced.

Therefore, the first option would have an effect more quickly but would not capture all of the target product group. The second option would take effect over a longer period of time and encompass the entire product group. It may be possible to design a policy option that could achieve the best virtues of each of these options.

It should be noted that any EU phase-out of mercury catalysts in PU elastomers will also have significant impacts far beyond the EU borders, as in the case of the global impacts of the RoHS Directive.

6.6.2 Main impacts and cost elements of selected policy options

The tables below provide an overview of the main impacts and cost elements of phasing out mercury-catalysed PU elastomers (MCPUEs). This impact analysis will focus especially on the qualitative elements.

Table 6-10 Benefits and costs of phasing out marketing of PU elastomer systems containing Hg

Impacts on:	Impact elements	Cost elements	Benefit elements
Raw material manufacturers, who are also typically involved in bulk imports and/or exports	Impact on manufacturers of polymers, polyols, isocyanates and other bulk chemicals	Decreased sales by EU manufacturers of some raw materials associated with MCPUEs, increased sales of others, and increased research costs to replace all MCPUE systems	
	Impacts on manufacturers of mercury compounds and other specialty chemical catalysts and additives	Decreased sales by EU manufacturers of Hg catalysts and some additives, increased sales of others, and increased research costs to replace all MCPUE systems	
Services and support industry, who may also import raw materials and/or export PU elastomer systems	Impact on services industry consulting and designing PU elastomer systems		Services industry will experience increased demand for help to identify viable substitutes for MCPUE systems
	Impact on industry designing and manufacturing PU elastomer casting, injection and spraying machines		Machine designers and manufacturers will experience increased demand for equipment to replace MCPUE systems using
Users, who may also be importers, of PU elastomer systems	Impact on industrial users who cast or spray PU elastomers for their own applications	These users will initially have less choice of PU elastomer systems, increased cost to identify or develop alternative systems	Reduced waste disposal costs, and possible problems of product reliability at first
	Impact on other users who cast and sell end-products made from PU elastomers	These users will initially have less choice of PU elastomer systems, increased cost to identify or develop alternative systems	Reduced waste disposal costs, and possible problems of product reliability at first

Impacts on:	Impact elements	Cost elements	Benefit elements
Users, who may also be importers, of PU elastomer products	Impact on purchasers and users of PU elastomer end-products cast by others	Higher prices for purchasers of some end-products, reflecting research and development costs to identify Hg-free systems	
EU society and others who are not direct purchasers or users	Impact on general society of mercury released during raw material and elastomer production processes		Reduced costs of environmental and health impacts of mercury emissions
	Impact on general society of mercury released during normal use and abrasion of PU elastomers		Reduced costs of environmental and health impacts of mercury emissions
	Impact on general society of mercury released from PU elastomers in various industrial and municipal waste streams		Reduced costs of environmental and health impacts of mercury emissions
	Impacts of mercury from long-range atmospheric transport of mercury from production processes in countries exporting to the EU		Reduced costs of environmental and health impacts of mercury emissions
	Impacts of mercury from long-range atmospheric transport of mercury from waste disposal in countries importing from the EU	No change unless EU marketing ban includes also an export ban	

Table 6-11 Benefits and costs of phasing out exports of PU elastomer systems containing Hg

Impacts on:	Impact elements	Cost elements	Benefit elements
Raw material manufacturers, who are also typically involved in bulk imports and/or exports	Impact on manufacturers of polymers, polyols, isocyanates and other bulk chemicals	Decreased sales by EU manufacturers of some MCPUE raw materials,	possible increased sales of others
	Impacts on manufacturers of mercury compounds and other specialty chemical catalysts and additives	Decreased sales by EU manufacturers of some MCPUE raw materials,	possible increased sales of others
Services and support industry, who may also import raw materials and/or export PU elastomer systems	Impact on services industry consulting and designing PU elastomer systems	Slightly decreased service revenues for MCPUE systems, possibly slightly increased service revenues for others	
	Impact on industry designing and manufacturing PU elastomer casting, injection and spraying machines	Decreased sales of some MCPUE equipment, possibly increased sales of other equipment	

Impacts on:	Impact elements	Cost elements	Benefit elements
Users, who may also be importers, of PU elastomer systems	Impact on industrial users who cast or spray PU elastomers for their own applications	No change	
	Impact on other users who cast and sell end-products made from PU elastomers	Decreased sales of MCPUEs, assuming export of Hg in end-products is also phased out	Possibly increased sales of Hg-free PU elastomers
Users, who may also be importers, of PU elastomer products	Impact on purchasers and users of PU elastomer end-products cast by others	No change	
EU society and others who are not direct purchasers or users	Impact on general society of mercury released during raw material and elastomer production processes		Reduced costs of environmental and health impacts of mercury emissions, in line with reduced EU production of MCPUEs
	Impact on general society of mercury released from MCPUEs in various industrial and municipal waste streams		Reduced costs of environmental and health impacts of mercury emissions, in line with reduced EU production of MCPUEs
	Impacts of mercury from long-range atmospheric transport of mercury from waste disposal in countries importing MCPUEs from the EU		Reduced costs of environmental and health impacts of mercury emissions, in line with reduced MCPUE products imported by third countries from the EU

It is evident from the above tables that any phasing out or reductions in exports of mercury-catalysed PU elastomers (MCPUEs) will have relatively minimal impacts because they will be largely offset by increases in trade of Hg-free PU elastomers.

The impacts of phasing out marketing and use of MCPUEs within the EU are somewhat more complex, and are further discussed below.

6.6.3 Impacts on EU manufacturers and the market

It is clear that any policy to phase out mercury-catalysed PU elastomers (MCPUEs) will incur a range of direct and indirect costs to industry. This section will assess whether such costs may be significant.

6.6.3.1 The EU polyurethane elastomer market

Accepting that Western Europe represents 22% of the global PU elastomer market (SRI 2006), this implies a total net consumption of some 350,000 tonnes per year in the EU27+2, including imports and exports of some 70-80,000 tonnes each. Of the total EU consumption of 350,000 tonnes, 12-18,000 tonnes are estimated to be catalysed with mercury. Industry contacts have pointed out that mercury catalysts are widely used in the UK, Spain and Italy; relatively little used in Germany, although the overall industrial output is very high; while France is somewhere in the middle. Other EU countries do significantly less PU elastomer processing (IMCD 2008; Shepherd 2008).

6.6.3.2 General structure of the PU elastomer industry in the EU

This section provides a general overview of the situation in the EU with regard to the PU elastomer industry – especially types of companies involved, revenues, and direct employment – in order to obtain a rough idea of the impact of various policy options at the EU level.

Main types of companies in the PU elastomer market

While there is significant overlap, there are four basic types of companies or business sectors that drive the PU elastomer business:

- Companies that produce the large-volume chemical raw materials (polymers, urethanes, polyols, isocyanates, etc.) for PU elastomer systems, such as Basell Polyolefins, BASF, DSM, etc.;
- Companies that manufacture specialty chemical catalysts and additives for PU elastomer systems, such as Thor, Johnson-Matthey, Shepherd, etc.;
- Companies that develop, package and market PU elastomer systems, such as Dow Hyperlast, Baxenden, etc.; IMCD focuses more on the supply of base raw materials for PU systems;
- Companies that use PU elastomer systems to enhance their own products or processes, or to produce products for other markets, such as IFS, Elastogran, Polymed, etc. These companies may range from relatively high-volume producers using machine casting to specialised offshore or basic automotive applications done by hand-casting.

6.6.3.3 The PU elastomer market and employment in the UK

For purposes of this analysis, the UK market has been more closely examined in order to better understand the EU industry structure and market as a whole.

UK net consumption of PU elastomers, including imports and exports of some 4-6 thousand tonnes each, is estimated to be on the order of 22-28,000 tonnes, or 6-8% of the EU total consumption. Of the total UK consumption of PU elastomers, some 2,000-2,500 tonnes are thought to be cured with mercury catalysts, reflecting the UK's somewhat greater tendency to rely on mercury catalysts than the EU average (IMCD 2008; IFS 2008).[10]

The two companies that dominate the market for PU elastomers in the UK are Dow Hyperlast and Baxenden, each accounting for some £30-35 million in annual sales. The latter describes itself as a "world leader in polyurethane technology," with 212 employees and 2007 revenues of approximately US$70 million (Baxenden 2008).

The UK net consumption of PU elastomers was estimated above at 22-28,000 thousand tonnes. Taking the typical PU elastomer "system" market price of £3-4/kg of raw materials, this implies a basic UK-wide market of £75-100 million (IMCD 2008). To this market must be added the

[10] It should be kept in mind that PU elastomer system users form a very diverse group. One industry source ventured that the "hand-mix" users in the UK may rely on mercury-catalyzed PU elastomer systems for over 50% of their consumption.

provision of machinery, equipment and services that revolves around the sale and use of the raw materials, estimated at around 15% of the raw materials market, or £12-16 million. Finally, one must also add the value of PU elastomer products produced with these systems and sold on the market as final products or components. For this purpose, it is assumed that around half of the PU elastomer consumed is transformed into various products and resold at about twice the original system cost. The other half of the PU systems are assumed to be used on site, e.g. off-shore drilling applications, which create jobs but no direct revenues for the companies using the systems.

This adds up to a total UK market for PU elastomers of some £190 million (plus or minus perhaps 20%), of which about £23 million may be attributable to PU elastomers catalysed with mercury. Using a range of estimates for business revenues per direct employee it is estimated that over 2,500 persons are employed in the UK in the PU elastomer industry, of which 300-350 full-time jobs, or some 12%, may be attributable to PU elastomers catalysed with mercury.

6.6.3.4 The PU elastomer market and employment in the EU

The EU polyurethane elastomer market

As described in section 6.6.3.1, the net EU consumption of PU elastomers is some 22% of global consumption, or about 350,000 tonnes, of which some 20-25% represents imports, and a similar volume is exported. Approximately 80% of the EU commercial activity dealing with PU elastomers takes place in the main chemical industry centres of Germany, the UK, France, Italy and Spain (Shepherd 2008; IMCD 2008). Of the total EU consumption of PU elastomers, some 12-18,000 tonnes are estimated to be cured with mercury catalysts.

Economics of PU elastomer companies in the EU

Based on the UK analysis in section 6.6.3.3, and assuming a similar PU elastomer “system” market price of £3-4 (or an average of €4.9) per kg of raw materials, this implies an EU-wide market comprised of:

- the PU elastomer raw materials market of €1.5-2.0 billion, employing 8-9,000 persons;
- the provision of machinery, equipment and services that revolves around the sale and use of the raw materials – a market of €250-300 million, employing 1,300-1,500 persons;
- the value of PU elastomer products produced with these systems and sold on the market as final products or components – a market of €1.5-2.0 billion, employing over 15,000 persons; and
- about half of the PU systems assumed to be used on location – creating another 8-9,000 jobs but no direct revenues for the companies using the systems.

In summary, the PU elastomer industry in the EU is therefore responsible for some of €3.5-4.0 billion in revenues, and as many as 34-38,000 jobs.

With regard to that part of the industry that depends at present on mercury catalysts, the estimate indicates that for the EU as a whole, this segment of the industry enjoys €200-250 million in revenues, and is responsible for over 2,000 direct jobs.

6.6.3.5 Cost of identifying alternative systems

It has been estimated by industry contacts that 80% of present MCPUE systems may be relatively easily replaced with mercury-free systems, while the other 20% are not impossible but would require additional time. Nevertheless, assuming a clear incentive such as legislation, and with the further legislative assurance of a level playing field, within 5 years virtually all MCPUE systems could be mercury-free.

Further investigation revealed that industry considers a “relatively easy” substitution may be defined as research carried out by one (equivalent) researcher over 7-8 weeks, plus overhead and materials, for a total of some €10-15,000. Alternatively, a more challenging substitution might imply an investment of €25-40,000.

Quite conservatively, one could assume that an investment would be required to replace every MCPUE system. In practice, many of the MCPUE systems would be simply discontinued and replaced by an alternative mercury-free system that is already “on the shelf.”

Based upon a detailed investigation of the UK situation, some 30-45 different MCPUE systems are marketed, implying approximately 50-70 tonnes (average) of MCPUE sold annually for each system. At the EU level, recognizing that many systems are marketed in more than one EU country, it is estimated that there may be as many as 200-250 different MCPUE systems.

Replacing 200 MCPUE systems at €10-15,000 per system, and another 50 systems at €25-40,000 per system would result in investment costs of some €3.5-5.0 million, which could be spread over several years, depending on the policy chosen. A disadvantage of requiring a phase-out over too brief a period of time would be possibly significant “opportunity costs.” This means that the same researchers who would typically be developing new systems for new products would instead be required to spend their time searching for MCPUE system substitutes. In monetary terms, if a phase-out were implemented over 3-5 years, the opportunity cost might add only 10-20% to the €3.5-5.0 million calculated above. If the phase-out were required over 2-3 years, the opportunity cost might add as much as 40-50%. Therefore, the total investment cost could be €4-7 million (spread over several years), depending on the length of the phase-out.

This corresponds to costs of about €200 per kg of annual mercury use reduction. If the investment is allocated over 5 years production it correspond to about €40 per kg mercury phased out.

Since machinery and equipment used for mercury-free systems is virtually the same as that used for MCPUE systems, machinery and equipment would not be a significant source of increased costs. Consulting and development costs will be incurred to some extent, but will not much change the investment range calculated above.

It should be kept in mind that all investment costs required to shift to mercury-free catalysts may be expected to be internalised by industry and allocated to slightly increased product costs for Hg-free systems. If we keep in mind that those business sectors investing to replace MCPUE systems have total revenues on the order of €2 billion per year, then additional investment costs of €4-7 million (spread over several years) would have a small impact on product or end-user costs.

6.6.3.6 Mercury-free PUE system costs and reliability

There is no documentation or suggestion by industry that Hg-free PUE systems are more or less costly than MCPUE systems. Therefore, the mere fact of being obliged to use a mercury-free system instead of a mercury-catalysed system does not imply any change in cost. On the other hand, if the Hg-free system has slightly different properties from those of the mercury-catalysed system, then there could be issues of product reliability, etc., at least in the near term, until such problems are worked out. This would be mostly an issue of inconvenience, but could also entail some higher costs.

It has been demonstrated above that the overall cost to the end-user of a PUE system should not increase noticeably as a result of the industry internalizing extra research and related costs associated with identifying substitutes for MCPUEs.

6.6.3.7 Impact on jobs

Likewise, since MCPUE systems will typically be replaced by mercury-free systems, there are no appreciable job losses to be considered. On the contrary, the period of research to find alternatives to existing MCPUE systems, as well as future research beyond what might have been needed if the “more forgiving” mercury catalysts were still available, are clearly net creators of new jobs.

6.6.3.8 Waste from manufacturing of catalysts and PU elastomers

With regard to impacts on the hazardous waste stream, and related costs of phasing out MCPUEs, it is evident that bulk chemical and specialty chemical manufacturers frequently deal with various hazardous wastes during the normal course of business. Therefore, if bulk chemicals and catalysts for MCPUEs are no longer produced, the subsequent reduction of mercury waste in that waste stream should have a positive but small impact.

PU elastomer system users will have reduced waste disposal costs that could be significant. In any case of mixing mercury-containing two- or three-part systems there will some residues that should be disposed of as hazardous waste. It is clear that at present many of these residues are not disposed of as hazardous waste, but instead are sent to the municipal waste stream. Therefore the phasing out of MCPUE use will have a positive impact on both the hazardous waste stream and the municipal waste stream.

6.6.3.9 Timing of policy measures

The timing of a phase-out of MCPUEs has some important implications. Most importantly, in order to adequately educate the many large- and small-scale users of PU elastomer systems, a phase-out period of at least three years would be preferable. Industry sources have suggested that many small-scale users (typically users of hand-cast systems) may be unaware that they are using mercury-catalysed systems, and an awareness-raising process could take some time. In general, time will be required for users to inform themselves of viable mercury-free systems and properties, assess reliability issues, and deal with any waste problems related to previous use of mercury-catalysed systems.

6.6.4 Impacts on the end users of PU elastomer part and the users of the end products

Although the mercury catalysts ends up in the final product it has no function in the cures PU elastomer. The end users of elastomers e.g. in a non spark hammer, silk screen wiper blades or printing rolls would not face any differences in the final product from the substitution of the mercury catalysts.

It cannot be excluded that the costs of development of the mercury free MCPUE systems would be allocated to the end user as increased prices. After the system is developed, the use of alternative catalysts do not typically involve any extra costs. It is estimated above that the investment costs if allocated over 5 years production correspond to about €40 per kg mercury reduction. Whether these costs are allocated to the final product is difficult to say, but for a first indication of the level of possible costs to the end users, it will be assumed that the extra cost to the users might be €40-100 per kg substituted.

Until now there has been no attention to the effect to the user of mercury-catalysed PU apart from the previous awareness in the USA regarding mercury releases from PU floors in schools mentioned in 2.7.1.2. Nor has there been any awareness of the large amounts of mercury ending up in the waste streams with PU elastomer products, and the end users of the products have typically not taken any particular measures with regard to disposing of the products. Phasing out or banning mercury in the products consequently would accrue no significant benefit for the users with regard to the costs of waste disposal.

6.6.5 Impacts on civil society

Mercury-containing PU elastomers may be a significant, but until now unnoticed, source of mercury in the general waste stream and be a significant source of mercury emission from waste incinerators and landfills.

Impacts on society related to a phase-out of MCPUEs, while very difficult to quantify, may be significant. In this case, all societal impacts are beneficial as they relate to:

- reduced occupational exposures to mercury, whether during the manufacturing process, during machine-casting, during hand-casting, or associated with waste disposal;
- fewer health effects due to lower mercury releases to ambient air from product use and abrasion, from general deterioration of products over time, from processing and product waste that goes to incineration or landfill, and from mercury that eventually enters the food chain; and
- decreased environmental impacts as a result of the reduced mercury emissions described above, which also have an impact on the food chain of organisms and wildlife.

6.6.6 Conclusions

In conclusion policy option a2, proposing a phase-out of the use of mercury in polyurethane elastomers over a 3-5 year period, would appear to be preferable to other options, with overall positive impacts on the economy and society. Further refinements to this policy option should be considered, such as requiring before 3 years a request for exemption from any stakeholder who cannot comply with a 3-year phase-out, and a complete ban after 5 years with no further exemptions.

It should be kept in mind, as in other mercury product applications, that aerospace, marine and military applications of PU elastomers may claim exemptions for reasons of safety, reliability, security, etc. This research suggests that all such users of PU elastomer applications – if they take the phase-out period seriously – should be able to identify mercury-free alternatives within a three- to five-year time frame. Moreover, there will not be many suppliers of PU elastomer systems interested in stocking a mercury-catalysed product for a relatively small and declining market.

Finally it bears repeating that the global impact of such a phase-out will be significant. On the one hand, other countries have shown a willingness to follow the EU lead toward better mercury management and environmental responsibility. On the other hand, industry has little interest in selling a different product within the EU from that marketed outside the EU, which may not only be commercially inefficient, but also leaves industry open to criticism of applying different standards to different markets.

Overall, expected non-quantified costs to the PU elastomer industry over a five-year period due to a three- to five-year phase-out of mercury use in PU elastomers are summarised in Table 6-12 below.

Table 6-12 General costs of a five-year phase-out of EU mercury use in PU elastomers

	Impact elements	Cost impact	Benefits
Impact on professional users	change in product cost	€40-100 per kg mercury	
	change in waste disposal cost		++
	decreased reliability (short term)		
Impact on consumers of end-products	change in product cost	€40-100 per kg mercury	
	change in waste disposal cost		++
	decreased reliability (short term)		
Impact on the waste stream	less hazardous waste		+
	less Hg in municipal waste		++
	enhanced recycling of PU elastomers		+
Impact on environment	reduced industry releases of Hg		+
	reduced product releases of Hg		+
Impact on human health	reduced occupational exposures		+
	reduced food-chain exposures		+
Impact on manufacturers	required investment	[factored into impacts on professional users and consumers of end-products]	
	competitiveness		
	jobs created		
Impact on global market	less hazardous waste disposal		+
	less Hg in municipal waste		++
	reduced industry releases of Hg		+
	reduced product releases of Hg		+
	reduced occupational exposures		+
	reduced food-chain exposures		+

+ + = significant benefits
+ = marginal benefits
0 = no change
– = marginal costs
– – = significant costs

6.7 Mercury porosimetry

Mercury is used in mercury porosimetry for characterisation of pore structures of materials.

The total amount of mercury used for the application in the EU has been estimated with high uncertainty at 10-100 tonnes per year. The total number of users of the method in the EU is estimated at 1000-2000. The equipment is used in laboratories for research and material quality control.

Alternatives for reducing or preventing mercury use for porosimetry
Two alternatives to mercury porosimetry are commercially available today; they are described further in section 2.8.1.1. The alternatives currently have some limitations as regards measurable materials and pore sizes. One currently available method, "water intrusion", can only be applied on hydrophobic (water-rejecting) materials. The other method "extrusion" can only measure poresizes within the range 0.06 µm - 1000 µm, it does not work with dead-end pores, and requires that one side of the sample is cut to a plane surface (which in some cases is not desirable). It seems reasonable to expect that the intrusion method could maybe be developed to include hydrophilic materials, but this principle is applied commercially at present. Furthermore, the alternative methods do not measure exactly the same characteristics as the mercury porosimeter, and therefore a change in methods will require the users' research on comparability between the methods ("translation" of pore characterisation data between the methods), and perhaps some compromises as regards the characterisation. The measurement of pore characteristics is based on analysis standards, and establishment and a wide use and acknowledgement of new standards usually take time.

A manufacturer of porosimeters using both mercury and the alternatives state that most of the existing porosimeters globally are using the mercury method. According to the same manufacturer, the alternatives are less costly both as regards instrument investments and elimination of costs for safe management of the mercury involved. The data transition work will imply certain costs.

Only Sweden has indicated having information on the level of substitution and has answered the questionnaire with a 3: “Alternatives dominate the market, but new products with mercury also have significant market shares”.

Current community level legislation and other measures
The area is not covered by current community level legislation.

Legislation beyond EU legislation in force in Member States, Norway or Switzerland
The general ban on sale and use of mercury in Norway also ban the use of mercury in porosimetry. The impact assessment of the ban does not specifically include the availability of alternatives.

Sweden has a general ban on the use of mercury in measuring equipment, but has granted a number of exemptions for mercury porosimeters.

Netherlands have an exemption to the general ban for mercury porosimeters.

The general ban on mercury in products in Denmark do not specifically have an exemption for mercury porosimeters, but most applications would fall under the exempted category, “Products for research”.

6.7.1 Main options for reducing or preventing mercury use in porosimetry

Policy options for reducing mercury use in porosimetry are listed in the table below. Self-regulation and economic incentives are not considered relevant options for this product group.

	Option		Effect on mercury in new products
Community legislation	a1	Extent the ban on liquid mercury in measuring devices in 76/769/EEC to include placing on the market of porosimeters for mercury porosimetry 76/769/EEC has a general exemptions for marketing or use for Research and Development or analysis purposes.	Limited effect as most applications would be exempted
	a2	General ban of marketing of porosimeters for mercury in porosimetry	Short term: Reduce mercury input to society of 1-10 tonnes per year Long term: Reduce mercury input to society of 10 - 100 tonnes per year
	a3	General ban of use of mercury for porosimetry (including existing equipment)	Reduce mercury input to society by 10-100 tonnes per year
	a4	Requirements of the use of mercury traps	Perhaps slight reduction of the releases of mercury from porosimetry, number unknown
Self-regulation	b1	No obvious options	
Economic incentives	c1	No obvious options	

Policy options selected for further analysis

Option a1, would be most consistent with existing EU regulation, but would have an insignificant impact on the use of mercury for this purpose as nearly all applications would fall under the definition of Research and Development or analysis purposes.

Option a3, a general ban of marketing of mercury for porosimetry (including use of existing equipment), would imply that porosimeters in 1000-2000 enterprises and research institutions should be replaced and new methods phased in, and at the current stage this would imply significant costs and have significant consequences on the research and development activities within EU enterprises and institutions.

The potential for release reductions of option a4 is difficult to assess. It is likely minimal, however, seen on a national or regional scale as most lost mercury likely follows the waste sample, when analyses are run under proper conditions. Such release reduction measurements are, however, considered important for the working environment and the immediate surroundings of the laboratory facilities. This option has not been assessed further here.

For these reasons option a2 is selected for the further assessment.

Main impact and cost element of selected policy options

The main impacts and cost elements of a general ban of marketing of porosimeters for mercury in porosimetry are shown in the table below.

Table 6-13 Impact and cost elements of prohibiting marketing of porosimeters for mercury porosimetry and the use of mercury for porosimetry

Impacts on:	Impact elements	Cost elements	Benefit elements
Manufacturers	Impact on manufacturers of mercury-containing equipment	Reduced sale of mercury measuring equipment	
Users of the equipment: Companies and research institutions	Impact on the price of equipment	Reduced costs of equipment	
	Impacts on which pore structure characteristics can be obtained	Increased costs for research and development of new methods to fully substitute Hg Increased costs for development of new standards and standard materials	
	Comparability	Increased costs for comparing new pore structure data with previously obtained results	
	Impacts of the spill of mercury		Reduced costs of mercury spill kits and spill response preparedness Reduced costs of clean up of mercury spill
	Waste disposal		Reduced costs of disposing of contaminated samples and contaminated mercury
	Working environment		Reduced costs of health impacts and exposure reduction equipment in the working environment
Society	Impacts of releases from operation of equipment and spill		Reduced costs of health impacts Reduced costs of environmental impacts
	Waste disposal		Reduced costs of environmental and health impacts of mercury released from waste operations and landfills

6.7.2 Impacts on EU manufacturers and the market

Mercury porosimeters is manufactured by one company in the EU. The company does not manufacture alternatives and would impacted negatively by a possible ban of marketing of mercury porosimeters. The employment by the company for manufacturing of porosimeters has not been assessed further.

6.7.3 Impacts on the users of the equipment and waste disposal

Costs to the users for purchase of equipment and materials usage
Based on a limited data material, the costs of mercury-free porosimeters are lower than for the mercury using instruments. Additionally, substantial costs are associated with the safe usage and handling of mercury in the laboratory, in waste disposal and release prevention, and these costs can be limited with the mercury free methods.

Development and introduction of alternative methods
As the currently commercially available alternatives do not cover all measurements made with the mercury intrusion method, expenses should be foreseen for a possible development of alternatives covering all situations. In case the use of mercury for porosimetry is regulated, it is likely that the alternatives will be developed further. Until fully covering alternatives exist, an exemption to a ban will be necessary for (at least) the measurement of hydrophilic samples for which pore sizes outside the range 0.06 µm - 1000 µm are important for documentable technical reasons.

For all relevant types of pore materials, comparable measurements with the mercury intrusion method and the alternative measurements will be necessary to document comparability (to the extent they are not done already). Such comparability studies may be done as general research (e.g. by manufacturers of porosimeters), or they may be necessary for individual users of the alternative porosimeters. Such individual phase-in programmes do take place according to a manufacturer of the alternative porosimeters. Such comparability studies are associated with costs, mainly for the users of the porosimeters (and their customers in case of commercial laboratories).

Standards
The determination of pore size distribution by use of mercury porosimetry is defined by a number of international or national standards.

ISO 15901-1:2005 "*Pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption -- Part 1: Mercury porosimetry*". ISO 15901-1:2005 describes a method for the evaluation of the pore size distribution and the specific surface in pores of solids by mercury porosimetry. It describes a comparative test, usually destructive due to mercury contamination, in which the volume of mercury penetrating a pore or void is determined as a function of an applied hydrostatic pressure, which can be related to a pore diameter. Among national standards are the German DIN 66133:1993-06. "*Determination of pore volume distribution and specific surface area of solids by mercury intrusion*" and the British Standard, 1992-11-15 *"Porosity and pore size distribution of materials - Method of evaluation by mercury porosimetry"*

The development and adoption of new standards imply costs for testing (as described above) as well as for organizational activities involved in the adoption.

Reduced costs of spill and releases
The establishment of laboratory facilities to accommodate a hazardous substance like mercury appropriately require substantial equipment investments besides the measurement instruments themselves: Fume hoods, ventilation and fume stacks - perhaps equipped with mercury retention filter, flooring, piping and vessels for containment of spills and cleaning water. A container for safe and sufficient storage of mercury waste, including contaminated samples, is also needed. In case of spill incidents, the decontamination of the laboratory involves labour expenses, and perhaps the replacement and disposal of contaminated construction materials.

Costs of treatment of Hg waste
Besides the investments in protective installation and clean-up of spills mentioned above, the safe transport and treatment of mercury-containing waste represents a significant cost. In case this waste is not treated as hazardous waste with appropriate precautions, the mercury will enter the general waste flow with consequences for health and environment, and associated costs.

6.7.4 Costs to society

The reduction of mercury usage for porosimetry would be associated with reduced costs of health impacts and environmental impacts from direct mercury releases in the working environment and in the immediate surroundings of the laboratory facilities, as well as from indirect releases of mercury from waste operations and landfills.

6.7.5 Conclusions

This study has emphasised that the mercury consumption for porosimetry is substantially larger than previously expected; in fact this use may be among the largest remaining uses in the EU today. The mercury usage takes place in laboratory conditions, which tend to ensure a certain containment of the mercury. Direct releases to the environment are expected, however, and due to the substantial amounts of mercury involved, the generated mercury-containing waste contributes significantly to the mercury input to waste in the EU. These preliminary findings indicate that it might be useful to investigate this mercury usage in more detail in future work, and that regulation may be warranted in the longer perspective.

Two alternatives to mercury porosimetry are commercially available today. They currently have some limitations as regards measurable materials and pore sizes, and investment costs should be foreseen for a possible development of alternatives covering all situations. Unless mercury use for porosimetry is regulated, it is likely that the further development and implementation of alternatives will be slow. The measurement of pore characteristics is based on analysis standards, and establishment and a wide use and acknowledgement of new standards usually take time. Also, the alternative methods do not measure exactly the same characteristics as the mercury porosimeter, and therefore a change in methods will require the users to carry out research on comparability between the methods.

Until comprehensive alternatives exist, an exemption to a ban on the sale of new mercury porosimeters would be necessary for (at least) the measurement of hydrophilic samples for which pore sizes outside the range 0.06 µm - 1000 µm are important for documentable technical reasons. Except for industries' quality control of a very specific range of materials, many users would in effect be covered by such an exception.

6.8 Policy options for mercury in lighthouses

The total mercury quantity accumulated in light houses in the EU is estimated at 24 - 125 tonnes mercury (see section 2.8.3). Each lighthouse contain on average 120-250 kg mercury. By the decommissioning of the light houses the mercury is typically disposed of for recycling.

According to the new Regulation (EC) on the banning of exports and the safe storage of metallic mercury, mercury that is no longer used in the chlor-alkali industry, metallic mercury gained from the cleaning of natural gas and metallic mercury from non-ferrous mining and smelting operations shall be disposed of for safe storage.

The aim of the safe storage of metallic mercury is to reduce the supply of mercury in the EU.

I would be consistent with the objectives of the regulation to include mercury that is no longer used in light house in an amendment to the regulation. The relatively large amounts of mercury stored in each light house makes it feasible to send the mercury directly for safe storage.

The impacts of the extension would be the same as the impacts of the regulation on mercury from chlor-alkali industry, however the impacts would be much smaller, as the quantities accumulated in the chlor-alkali industry is more than 100 times the quantities accumulated in light houses.

6.9 Policy options for mercury compounds used as biocides

On the basis of Member States' questionnaire responses and industry contacts, the EU-wide consumption of mercury with preservatives in water-based paints is estimated at 4-10 tonnes mercury. According to the questionnaire response Italy the used substances are phenylmercury acetate and phenylmercuric 2-ethylhexanoate.

Producers and formulators had to either identify or notify all existing active substances to the European Chemicals Bureau (ECB) before 31 January 2003. A list of notified substances obtained from ECB does not include any mercury compounds.

No mercury-containing products are neither included in the list of substances covered by the review programme (EC 2007b), nor in the list of existing active substances for which a decision of non-inclusion into Annex I or Ia of Directive 98/8/EC has been adopted or in the lists of included substances.

Member State may, for a period of 10 years from the date of transposition (13 may 2000 as the latest) continue to apply its current system or practice of placing biocidal products on the market. The 10 years period expire the 13 May 2010 as the latest, and after this date, no biocidal products with mercury compounds would be allowed in any Member State.

As the use of mercury compounds as biocides will discontinue within the next two years, no further actions are proposed, but the necessary enforcement of the Biocide Directive in Member States with use of mercury biocides should be ensured.

6.10 Summary across policy options

As the assessment of some impacts of policy options, especially the benefits of different policies, has been largely qualitative, it is not feasible to perform a comprehensive comparison of the different policy options. Based on the various costs calculated, however, it is possible to make a comparison of the policy options as regards cost-effectiveness – specifically in terms of cost to the end-user per kg reduction in mercury input to society.

In spite of the broad range of uncertainties in some calculations, the analysis clearly indicates that the costs of substituting one kg of mercury in sphygmomanometers, barometers and PU elastomers are very small compared to the costs of substituting one kg of mercury in dental amalgam or thermometers.

For both mercury sphygmomanometers and PU elastomers, the quantities of mercury that could be eliminated by these policy options are very significant as compared to the total mercury consumption in the EU. Furthermore, the assessment demonstrates that the impact on EU manufacturers of a restriction of mercury use for these two applications will be very small, and on balance, the overall impact would be positive.

A ban on the marketing of mercury-containing PU elastomers would also have a very significant impact on the total amounts of mercury directed to general waste, as these elastomer products today are neither separated for recycling nor disposed of as hazardous waste.

The relatively high cost of substituting dental amalgam is mainly due to increased time for preparing the filling, and much less to the increased price of the alternative filling material. The relatively high cost of substituting thermometers is because alternatives are relatively costly, and the mercury content of one thermometer is small compared to the content of a sphygmomanometer that has 20 times more mercury than the thermometer. It should be noted that for many of the thermometers already phased out, the price of alternatives has not been significantly higher than the price of mercury thermometers for these applications.

Table 6-14 Overview of the main costs to end-users per kg reduction in mercury input resulting from different policy options

Product group	Policy option	Potential for reducing mercury input, (t Hg per year)	Cost to the end-user of reduced mercury input (€/ kg Hg)	Main constraints
Dental amalgam fillings	General ban on mercury in dental fillings	80 - 110	11,000 - 78,000	Price and some drawbacks of alternatives
Sphygmomanometers	Extend the ban on marketing of liquid mercury in measuring devices in 76/769/EEC	3 - 7	(-26) - 99	Lack of clear statements from the medical authorities regarding reliability of alternatives
Thermometers		0.2 - 0.6	5,000 - 20,000	Price of alternatives; use of mercury thermometers as analytical standards
Barometers		0.1 - 0.5	~0	Tradition
PU elastomers	Ban on marketing of mercury catalysts in PU elastomers	20 - 35	40 - 100	Time needed for customised development of mercury-free systems
Porosimetry	Ban on the marketing of mercury porosimeters	2 - 20 (short term)	not yet quantified	Alternatives are not available for all applications

For all applications there should be some benefits due to reduced handling of mercury-containing waste, but for measuring equipment these benefits are assumed to be relatively modest as most alternatives would also require some special treatment (e.g. as electronic waste).

A reduction of the input of mercury to society would result in reduced mercury exposures and reduced emissions to the environment over both the short and the long term. The health benefits of various policy options have not been assessed in this study, although the health benefits due to reduced atmospheric mercury emissions have been estimated in recent research carried out in the USA, as described in section 6.3. The US research calculated health benefits equivalent to €4,000-110,000 per kg reduction in mercury emissions whereas a recently published study from the Nordic Council of Ministers apply a cost of approximately $12,000 per kg mercury emitted. That benefits of reduced mercury emission is not directly comparable to reduced use of mercury in products since:

- it cannot be assumed that all mercury used in products goes to atmospheric emissions;
- some mercury used in products is emitted to water, and the benefit of eliminating such emissions is considered to be higher than the benefit of eliminating the same quantity of atmospheric emissions;
- benefits related to a reduction in management of Hg product waste should be considered;
- other health benefits related to reduced mercury use in products, such as exposures in the workplace, exposures during product use/breakage, etc., should be considered;

Nevertheless the benefits calculated by US researchers provide a very useful basis for comparison. That range of benefits suggests that, purely on the basis of expected health benefits, dental amalgam and thermometers should be seriously considered for further restrictions, while the benefits of reducing the mercury input due to sphygmomanometers and PU elastomers seems to be significantly higher than the costs and measures may put forward as soon as possible.

For dental amalgam waste, which represents the major source of mercury input to wastewater in many Member States, the impacts and costs of obligatory installation of high-efficiency amalgam separators in dental clinics have been analysed. The costs are estimated at €1,400-1,800 per kg reduction in Hg releases. Ignoring costs of dealing with other amalgam wastes, etc., one could simply compare the cost of separators to the cost of substitution of dental amalgam, and observe that the cost of separators is some ten times less per kg of mercury removed from circulation. On the other hand, a gradual phase-out of dental amalgams permits the EU to deal more simply with the entire range of environmental and human health effects related to the varied mercury releases – including cremation releases, wastewater sludge releases, etc. – associated with the use of mercury in dentistry.

Among other applications, the cases of improved management of mercury in lighthouses, and restricting the use of mercury in biocides have been highlighted in this study. Policy options for these applications have not been analysed in detail, but it has been considered whether some policy options are immediately obvious. It is proposed to consider including mercury from decommissioned lighthouses in the new Regulation (originally tabled as COM(2006)0636) on the banning of exports and the safe storage of metallic mercury. With regard to the use of mercury compounds as biocides, the analysis shows that this application will virtually end within the next two years, as none of the relevant mercury compounds have been notified or included in the review programme. For this reason no policy measures have been proposed for this application.

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Annex 1
Substitution of mercury products and processes

The following indications of substitution level in Member States has been obtained by the use of a questionnaire to the 27 Member States, Norway and Switzerland, December2007. Ten countries responded to this part of the questionnaire.

Index	Description of substitution level
0	No substitution indicated in assessed data sources; development may be underway
1	Alternatives are in commercial maturation, or are present on the market but with marginal market shares
2	Alternatives are commercially matured and have significant market shares, but do not dominate the market
3	Alternatives dominate the market, but new products with mercury also have significant market shares
4	Mercury use is fully, or almost fully, substituted
N	No knowledge of substitution level

Mercury use (table continued over several pages)	**CH**	**DE**	**DK**	**FI**	**FR**	**HU**	**IT**	**LI**	**SE**	**UK**
Intentional use of mercury in industrial/production processes										
Chlor-alkali production with mercury cells	4	2	N	3	3	1			4	
VCM (vinyl-chloride-monomer) production with mercury-dichloride (HgCl2) as catalyst		N	N	N	N	N			4	
Acetaldehyde production with mercury-sulphate (HgSO4) as catalyst		N	N	N	N	N			4	
Polyurethane production (Hg catalysts)		N	N	N	N	N			4	
Vinyl acetate production (Hg catalysts)		N	N	N	N	N			-	
Production of the cube (1-amino anthrachion) colours/pigments with Hg catalyst		N	N	N	N	N			-	
Small scale gold and silver mining		-	N	4		4			-	
Consumer products with intentional use of mercury										
Dental amalgam fillings	4		3-4	3		3		3	4	
Skin lightening creams and soaps		4	4	4		N		4	4	
Thermometers containing mercury:										
Medical thermometers	4		4	4	4	2		3	4	3
Other glass thermometers (laboratory, educational, etc.)	3		3-4	3		N		0	4	
Other (non-glass) mercury thermometers (industrial, marine diesel engines, etc.)	4		4	N		N			4	
Hygrometer/psychrometer (thermometer-based)	N		4	N		4			4	
Pyrometers (high temperature range thermometers)	N		4	N		N			4	
Electrical and electronic switches, contacts and										

Mercury use (table continued over several pages)	CH	DE	DK	FI	FR	HU	IT	LI	SE	UK
relays with mercury:										
Level switches (in sewer pumps, float switches, pressure switches, car hoods/bonnets, movement detectors, alarms, etc.)	4		4	4		N			4	
Multiple pole level switches in excavation machinery	4		4	4		N			4	
Mercury-wetted contacts (in electronics)	4		N	3		N			4	
Data transmission relays or “reed relays”	4		N	N		N			4	
Displacement (or “plunger”) relays	4		N	N		N			4	
Thermo-switches (thermostats)	4		4	N		N			4	
Infra-red light detection semiconductors	4		N	N		N			4	
ABS brake activators and airbag activators in cars	4		4?	N	4	N			4	
Continuous conductors in rotating seam welding wheels	4		N	N		N			1-2	
Ignitrons and Hg-arc rectifiers in AC/DC converters	4		N	N		N			4	
Light sources with mercury:										
Linear fluorescent lamps	0		4	0	0	1			0-1	
Compact fluorescent lamps (CFL, commonly called energy saving lamps/bulbs)	0		N	0	0	1			1	
Street advertisement with fluorescent “neon” tubes containing argon gas and Hg	0		4	N	0	N			3	
High pressure Hg and Na lamps (for street lighting etc.)	0		4	3	0	3			2	
Backlight in LCD flat screens	0		4	N		N			1	
In liquid diode material in LCD flat screens	0		4	N		N				
Laboratory atomic absorption spectrometry lamps	0		N	N		N				
Headlamps in some car models	0		4	N	0	N			4	
Exit signs (green signs in public buildings etc.)	0		4	N		N			4	
Batteries containing mercury:										
Mercury oxide /mercury zinc batteries (cylindrical and button)	4	4	4	4		N			4	
Alkaline cylindrical batteries (containing mercury)	4	4	4	4		N			4	
Zinc-manganese batteries (paste and paper types)	4	4	4	4		N			4	
Alkaline button cell batteries (containing mercury)	0	2	N	4		N			1	
Zinc-air button cell batteries	0	2	N	4		N			1	
Silver oxide button cell batteries	0	2	N	N		N			1	
Biocides and pesticides containing mercury:										
Agricultural pesticides (seed dressing, dipping sugar cane and grape seedlings, spraying insecticides, etc.)	4		4	4	4	4			4	
Slimicides/fungicides used in paper and paper pulp factories	4	N	4	4	4	4			4	
Preservation of wood (other than wood for paper production)	4	N	4	4	4	4			4	
Latex and other paints (Hg added for shelf life preservation and hindering mould on painted surfaces in humid conditions)	4	N	4	4	4	N	4		4	

Mercury use (table continued over several pages)	CH	DE	DK	FI	FR	HU	IT	LI	SE	UK
Antifouling paints for boats	4	N	4	4	4	N			4	
Pharmaceuticals for human and veterinary uses, including biocides in vaccines, in eye drops, some herbal medicines, disinfectants, etc.	3		N?	N	?	N			4	
Biocides for preservation of eye cosmetics and in liquids for contact lenses	N	N	4	N	?	N			4	
Manometers and pressure gauges:										
Blood pressure gauges (sphygmomanometers)	3		3-4	3		3		4	4	2
Blood pressure “strain gauge plethysmographs”	3		4	3		N			4	
Manometers/pressure controls for industrial uses, gas lines, district heating, etc.	4		4	4		N			4	
Barometers, meteorological	4		4	4		3			4	
Flow meters (gas flows, etc., applying a manometer)	4		4	4		N			4	
Manometers for educational purposes	4		4	4		N			4	
Laboratory chemicals and equipment:										
Specialized laboratory apparatus (Coulter Counters, tensiometers, and others)	N		N	N		N			1	
Chemical reactants for analysis (COD analysis, Kjeldahl analysis (nitrogen analysis), Nesslers reagent, etc.)	N		N	2		N			3	
Electrodes and references for physio-chemical measurements, such as calomel electrodes, references for Hg analysis etc	N		N	N		N			2-3 0-1	
Porosimetric analysis (pore size distribution)	N		N	N		N			3	
Other mercury metal uses:										
Marine navigation lights in lighthouses (in some types the lens/lamp unit floats on mercury)	N		4	N	0	N			4	
Ethnic/cultural/ritualistic uses and folklore medicine	n/a		4	4		N			4	
Gyroscopes/gyro compasses with mercury	N		4	4		N			4	
Vacuum pumps with mercury	N		4	4		N			4	
Mercury in large bearings of rotating mechanic part, for example, older wastewater treatment plants	N		4	4	4	N				
Miscellaneous products/processes not mentioned above:										0
Esophageal dilators (Bougie tubes) and gastrointestinal tubes with Hg	N		N	N		N			4	
Hydrometer (measuring density of liquids)	N		4	4		N			4	4
Tanning equipment (esp. lamps)	N		4	N		N				
Pigment (vermilion, HgS)	4		4	N		N	4		4	
Browning and etching steel	4		4	N		N			4	
Gilding	N		4	N		N			4	
Certain colour photograph paper types	N		4	N		N				
Recoil shock-absorbers in rifles	N		4	N		N			4	
Mercury fulminate, Hg(ONC)2, used as a detonator for	4		N 4	N		N			4	

Mercury use (table continued over several pages)	**CH**	**DE**	**DK**	**FI**	**FR**	**HU**	**IT**	**LI**	**SE**	**UK**
explosives, in ammunition and in fireworks										
Fireworks (other uses of Hg besides as detonator)	4		4	4		N			4	
Executive toys, pendants	N	4	4	N		N			4	
Neutron source in synchrotron light equipment and perhaps other high-intensity physical instruments	N		N	N		N				

Annex 2
Contacted companies and organisations

Chlor alkali production:

- Eurochlor, Belgium
- Natural Resources Defense Council, NRDC

Light Sources:

- European Environmental Bureau
- Lambert Metals
- Philips and Sylvania via ELC
- The European Lamp Companies Federation (ELC), Belgium

Batteries:

- Batrec Industrie AG, Switzerland
- Claushuis Metaalmaatschappij B.V., The Netherlands
- INDAVER BV, Belgium
- European Portable Battery Association (EPBA), Belgium
- European Battery Recycling Association (EBRA), Belgium

Dental amalgam:

- Ardent AB (Ivoclar Vivadent), Sweden
- Cavex Holland BV, The Netherlands
- DMG Chemisch Pharmazeutische Fabrik GmbH, Germany
- DMP Dental Materials Ltd,
- Dr. Ihde Dental GmbH, Germany
- Ivoclar Vivadent AG, Sweden
- Nordiska Dental AB, Sweden
- SAFINA, a.s., Czech republic
- Specialities Septodont, France
- SS White Group, UK

Switches and relays:

- ATMI, France
- Comus International Bvba, Belgium
- E.L.B. Füllstandsgeräte Bundshuh GmbH & co., Germany
- Hermetiko Bauteile GmbH, Germany
- MATIC srl., Italy

Measuring and control equipment:

- A.C. Cossor & Son Limited, UK
- ALLA, France
- Amarell GmbH & Co. KG, Germany
- Barometer World Limited, UK
- Eucomed, Belgium
- Guissani srl., Italy
- Kelvin Hughes Limited, UK
- Ludwig Schneider GmbH & co. KG, Germany
- Mercury Safety Products Ltd., UK

- Raytheon Anschuetz GmbH, Germany
- Rudolf Riester GmbH & Co. KG, Germany
- Russell Scientific Instruments Limited, UK
- SDEC France, France
- S. Brannan and Sons Limited, UK
- SIKA Dr. Siebert & Kühn GmbH & Co. KG, Germany

Mercury chemicals and catalysts:

- Acros, Belgium
- Bome, Czech Republic
- CFMOT, Germany
- Chemos, Germany
- European Vaccine Manufacturers (EVM), Belgium
- Fox Chemicals, Germany
- Gomensoro, Spain
- IFS Chemicals Ltd., U.K.
- IMCD UK Ltd., U.K.
- Johnson-Matthey, U.K.
- Lambert Metals, U.K.
- Mayasa/Minas de Almadén, Spain
- Safina, Czech Republic
- Scharlab, Spain
- Shepherd Chemicals, Switzerland, UK
- Technological Institute, Denmark

Miscellaneous uses:

- BN Instruments A/S, Denmark
- Carlo Erba Reagenti SpA, Italy
- Celco Profil, Italy
- Cemsa SpA., Italy
- Medovations Inc., USA
- Metrohm Nordic, Denmark
- Micromeritics Instrument Corporation, USA
- Porous Materials Inc., USA
- Quantachrome, Germany, UK
- Risoe, Department for fuel cells and solid state chemistry, Denmark
- Soudronic AG, Switzerland
- VEAT Verband, Germany

Collection and recycling:

- Batrec Industrie AG, Switzerland
- Bome s.r.o., Czech Republic
- Claushuis Metaalmaatschappij B.V., The Netherlands
- European Topic Centre on Resource and Waste Management (ETC/RWM), Denmark
- GMR Gesellschaft für Metallrecycling mbH, Germany
- INDAVER BV, Belgium
- Mercury Recycling Limited, UK
- NQR Nordische Quecksilber Rückgewinnung GmbH, Germany
- Quicksilver Recovery Services Ltd., UK
- RENAS, Norway
- SAKAB, Sweden

Annex 3
Comparison of blood pressure measuring devices

Table from MHRA (2006): Blood Pressure Measurement Devices. Device Bulletin, DB2006(03) July 2006. U.K. Department of Health, Medicines and Healthcare products Regulatory Agency (MHRA).

Equipment	Advantages	Disadvantages
Mercury sphygmomanometer (Price range £30 – £55)	'Gold standard', portable, good reliability, can be used on most patients.	• Contains a toxic substance leading to maintenance and disposal problems. • Manual technique prone to observer bias. • Requires clinical skill to operate.
Aneroid sphygmomanometer (Price range £20 – £80)	Mercury-free, portable, can be used on most patients.	• Wear and mechanical shock to mechanism may result in incorrect readings. • Requires regular calibration check. • Manual technique prone to observer bias. • Requires clinical skill.
Electronic sphygmomanometer (Price range £30 – £140)	Mercury-free, portable, good reliability, can be used on most patients.	• Manual technique prone to observer bias. • Requires clinical skill.
Semi-automated and automated spot-check device (Price range £30 – £170)	Mercury-free, lightweight, compact, portable, easy to use, no observer bias.	• Originally designed for home use, and may not be suitable for all patients, particularly those with arrhythmias, pre-eclampsia and certain vascular diseases. • Clinical validation recommended*.
Wrist device (Price range £20 – £100)	As above, with increased patient comfort.	• As for automated device above. • Readings are dependent on the relative positioning of the wrist to the heart. • Tends to be less accurate than upper arm devices.
Finger device (Price range £25 – £50)	As above.	• As for wrist device above, although measurement more peripheral and less reliable. • May not be suitable for patients with narrow or cold fingers.
Spot-check non-invasive blood pressure monitor (Price range £700 – £1,600) Automatic-cycling noninvasive blood pressure monitor (Price range £1,500 – £3,000)	• Mercury-free, no observer bias, portable, easy to use, designed for monitoring in clinical use. • May include additional vital signs	• May not be suitable for all patients, particularly those with arrhythmias, pre-eclampsia and certain vascular diseases • Clinical validation recommended*.
Ambulatory blood pressure monitor (Price range £1,000 – £2,000)	Mercury-free, lightweight, compact, designed for clinical use, records 24- hour blood pressure trend.	• Designed for ambulatory monitoring, not as a replacement for the mercury sphygmomanometer. • Clinical validation recommended*.

All prices are approximate and only serve as a guide to differentiate between types.

*Clinical validation as recommended by the Independent Advisory Group.

Annex 4
Mercury cell chlor-alkali plants in Europe (Jan. 2007)

COUNTRY	COMPANY	SITE	Cl_2 CAPACITY (000 TONNES)	MCCAPs IN 1990 (EST.)
AUSTRIA	(none operating)			2
BELGIUM	SolVin	Antwerp (Lillo)	330	4
	Tessenderlo Chemie	Tessenderlo	250	
CZECH REPUBLIC	Spolana	Neratovice	135	2
	Spolchemie	Usti	61	
DENMARK	(none operating)	Copenhagen		1
FINLAND	Akzo Nobel	Oulu	43	4
FRANCE	Albemarle	Thann	72	8
	Arkema	Jarrie	170	
	Arkema	Lavera	166	
	Arkema (decom. 2006)	Saint Auban	~~184~~	
	Prod. Chim. d'Harbonnières	Harbonnières	23	
	Solvay	Tavaux	241	
	Tessenderlo Chemie	Loos	18	
GERMANY	BASF	Ludwigshafen	160	17
	Bayer	Uerdingen	110	
	Vinnolit	Knapsack	120	
	Akzo Nobel	Ibbenbüren	125	
	Degussa	Lülsdorf	136	
	Ineos Chlor	Wilhelmshaven	149	
	LII Europe	Frankfurt	167	
	Vestolit	Marl	176	
	Vinnolit	Gendorf	82	
GREECE	Hellenic Petroleum	Thessaloniki	40	1
HUNGARY	BorsodChem	Kazincbarcika	137	5
IRELAND	(none operating)			1
ITALY	Altair Chimica	Volterra	27	13
	Solvay Ausimont	Bussi	87	
	Caffarro	Toreviscosa	68	
	Syndial	Porto Marghera	200	
	Syndial (decom. 2005)	Priolo	~~204~~	
	Eredi Zarelli	*Picinisco*	*6*	
	Solvay	Rosignano	125	
	Tessenderlo Chemie	Pieve Vergonte	42	
NETHERLANDS	Akzo Nobel (decom. 2006)	Hengelo	~~74~~	3
NORWAY	(none operating)			2
POLAND	Rokita	Brzeg Dolny	125	3
	Dwory (decom. 2005)	Oswiecim	~~39~~	
	Tarnow	*Tarnow*	*43*	
PORTUGAL	(none operating)			2
ROMANIA	S.C. Oltichim	Râmnicu Vâlcea	186	3
	Grupul Indus. de Petrochimie	Braila	5	
SLOVAK REPUBLIC	Novacke Chemicke	Novaky	76	2
SPAIN	EIASA (Aragonesas)	Huelva	101	10

COUNTRY	COMPANY	SITE	Cl_2 CAPACITY (000 TONNES)	MCCAPs IN 1990 (EST.)
	EIASA (Aragonesas)	Sabinanigo	25	
	EIASA (Aragonesas)	Villaseca	135	
	Elnosa	Lourizan	34	
	Ercros	Flix	150	
	Quimica del Cinca	Monzon	31	
	SolVin	Martorell	218	
	Solvay	Torrelavega	63	
SWEDEN	Akzo Nobel (decom. 2005)	Bohus	~~100~~	7
	Norsk Hydro	Stenungsund	120	
SWITZERLAND	SF-Chem	Pratteln	27	4
UNITED KINGDOM	Albion Chemicals (decom. 2005)	Sandbach	~~90~~	8
	Ineos Chlor	Runcorn	738	
	Rhodia (decom. 2005)	Staveley	~~29~~	
Totals		**45 operating**	**5543**	**102 plants**

Sources: Chlorine Industry Review 2004-2005, Euro Chlor, Brussels, 2005; Chlorine Industry Review 2006-2007, Euro Chlor, Brussels, 2007; Decommissioning of Mercury Chlor-Alkali Plants, Env. Prot. 3, 2nd edition, Euro Chlor, February 1999.

Notes: Recent decommissionings are noted in the table.

To complete the picture for greater Europe, there are 3 MCCAPs in Bosnia-Herzegovina of 17,000 t, 35,000t and 39,000t capacity; 4 MCCAPs in Serbia-Montenegro of about 5,000t, 8,000t, 115,000 t and 9,000t capacity, of which the latter 2 appear to be out of commission; 2 MCCAPs in Croatia of unknown capacity, possibly both out of commission; and 1 in Macedonia (Skopje) of 10,000t capacity, whose operational status is unclear. In addition to these, the former Yugoslavia had 10 additional MCCAPs operating in 1990.

ANNEX 5

Statistical data on production, import and export of mercury containing products

Import/export statistics, Comext

Data on export and import of relevant product groups were retrieved for the period 1999 to 2007 from the “Easy Comext" (or Easy XTnet) interface to the public at Eurostat’s External Trade database [11]. For the period 1996-1999 the datasets were in general empty and data fro these years are not included in the following tables. For each country data on import and export to/from EU27_intra (trade with other EU27 countries) and EU_extra (trade with countries outside EU27) was retrieved and reported in the following tables as the total import and total export (sum of EU_intra and EU_extra). For EU27 the total import and export divided on EU-intra and EU-extra trade in shown in the tables.

Many mercury-containing products (e.g. thermometers, measuring devices and switches) are included in products groups also comprising mercury-free equipment and the trade statistics is not useful for indicating the trade with the mercury containing products.

Production statistics, Prodcom

Data on production by relevant product groups were retrieved for the years 2004, 2005, and 2006 from Eurostat's Prodcom site [12]. Prodcom applies another nomenclature than the Combined Nomenclature (CN) which is used for the trade statistics. The Prodcom product groups and the product groups applied by the different Member States have traditionally been more aggregated that the CN product groups. The table overleaf shows the most recent Prodcom nomenclature for relevant product groups with reference to the corresponding CN groups. For the relevant product groups the Prodcom product groups has corresponding CN groups. The Prodcom data, however, have for the relevant product groups limited usability as data for each product group is only available from a few countries, partly due to confidentiality. Further it is from the tables not possible to distinguish between "no data" and 0 (zero).

[11] At: http://fd.comext.eurostat.cec.eu.int/xtweb/

[12] At: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2594,63266845&_dad=portal&_schema=PORTAL

Prodcom code	Prodcom description	Unit	CN code
24.13.13.80	Mercury	kg	2805.40
	- In flasks of a net content of 34,5 kg (standard weight), of a fob value, per flask, not exceeding € 224	kg	2805.40.10
	- Other	kg	2805.40.90
	Mercury oxide	kg	2825.90.50
24.13.41.85	Colloidal precious metals; compounds and amalgams of precious metals excluding silver nitrate	kg	2843 [.10 +.29 +.30 +.90]
	- Silver compounds, amalgams	kg	2843.10.00
24.13.42.70	Compounds, inorganic or organic, of mercury, excluding amalgams	kg	2852
-	Compounds, inorganic or organic, of mercury, excluding amalgams	kg	2852.00.00
31.50.15	Discharge lamps; ultra-violet or infra-red lamps; arc lamps		
31.50.15.10	Fluorescent hot cathode discharge lamps, with double ended cap (excluding ultraviolet lamps)	p/st	8539.31.10
31.50.15.30	Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps, with double ended cap)	p/st	8539.31.90
31.50.15.53	Mercury vapour discharge lamps (excluding ultraviolet lamps, dual lamps)	p/st	8539.32.10
31.50.15.56	Sodium vapour discharge lamps other than ultraviolet lamps	p/st	8539.32.50
31.50.15.59	Discharge lamps (excluding fluorescent hot cathode lamps, dual lamps, mercury or sodium vapour lamps, ultraviolet lamps)	p/st	8539 [.32.90 +.39]
	- Metal halide lamps	p/st;kg	8539.32.90
	- other	p/st;kg	8539.39.00
31.50.15.70	Ultraviolet or infrared lamps, arc lamps	p/st	8539.4
	- Ultraviolet lamps	p/st;kg	8539.49.10
31.40.11.12	Alkaline primary cells and primary batteries with a manganese dioxide cathode, button cells	p/st	8506.10.15
31.40.11.17	Non-alkaline primary cells and primary batteries with a manganese dioxide cathode, button cells	p/st	8506.10.95
31.40.11.23	Primary cells and primary batteries with a mercuric oxide cathode, cylindrical cells	p/st	8506.30.10
31.40.11.25	Primary cells and primary batteries with a mercuric oxide cathode, button cells	p/st	8506.30.30
31.40.11.27	Primary cells and primary batteries with a mercuric oxide cathode (excluding cylindrical or button cells)	p/st	8506.30.90
31.40.11.33	Primary cells and primary batteries with a silver oxide cathode, cylindrical cells	p/st	8506.40.10
31.40.11.35	Primary cells and primary batteries with a silver oxide cathode, button cells	p/st	8506.40.30
31.40.11.56	Air-zinc primary cells and primary batteries, button cells	p/st	8506.60.30

For the following two product groups no data are available in the Comext database and tables have consequently not been prepared.

2852 00 00 - COMPOUNDS, INORGANIC OR ORGANIC, OF MERCURY (EXCL. AMALGAMS).

8506 11 15 - MANGANESE DIOXIDE CELLS AND BATTERIES, VOLUME <= 300 CM3, ALKALINE, FORM OF BUTTON CELLS.

2805 40 10 - MERCURY IN FLASKS OF A NET CONTENT OF 34,5 KG, OF A FOB VALUE PER FLASK OF <= Â¿ 224								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	88	16	15	22	45	65	17	0
BULGARIA	0	1	0	1	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	1	0	1	1	1	0	0	0
DENMARK	0	0	0	0	0	0	1	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	14	3	2	1	20	8	0	0
GERMANY (incl DD from 1991)	19	8	7	4	20	19	0	24
GREECE	0	21	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	103	0	0	0	11	0	0	8
ITALY	17	8	20	13	1	18	0	16
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	204	61	169	29	9	103	16	34
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	1	1	5	1	0	0	0	0
ROMANIA	0	1	0	0	0	1	0	2
SLOVAKIA	0	0	0	0	0	1	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	17	7	76	69	12	170	272	176
SWEDEN	0	0	0	0	0	0	0	3
UNITED KINGDOM	1	0	0	0	5	1	0	0
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	28	0	42	16	9	0	9	0
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	7	10	5	20	0	0
DENMARK	0	0	1	0	5	2	2	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	37	83	78	55	26	24	32	25
FRANCE	3	2	0	1	4	0	1	0
GERMANY (incl DD from 1991)	124	143	67	21	20	14	4	6
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	0	0	10	145	6	1	4	13
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	136	202	224	193	84	104	28	89
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	0	0	0	19	0	7	2	0
ROMANIA	11	0	0	12	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	507	943	427	778	754	396	50	93
SWEDEN	0	0	0	0	0	0	0	0
UNITED KINGDOM	2	1	0	0	0	1	5	0
EU27_extra import	117	34	243	80	31	173	3	3
EU27_extra export	756	1010	710	1069	749	447	82	140
EU27_intra import	350	93	53	62	94	212	302	259
EU27_intra export	98	430	212	205	163	121	54	87

2805 40 90 - MERCURY (EXCL. IN FLASKS OF A NET CONTENT OF 34,5 KG, OF A FOB VALUE PER FLASK OF <= Â¿ 224).								
Data from COMEXT database	Import (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	2	0	3	6	19	4	1	2
BELGIUM (and LUXBG -> 1998)	12	5	3	0	1	4	3	44
BULGARIA	1	1	1	1	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	3	3	0	1	2	7	1	4
DENMARK	1	1	1	0	0	0	0	0
ESTONIA	0	0	0	0	3	0	1	0
FINLAND	13	0	0	0	0	1	0	0
FRANCE	187	29	21	24	38	291	210	138
GERMANY (incl DD from 1991)	8	52	62	17	19	63	44	48
GREECE	4	1	125	0	11	0	1	1
HUNGARY	3	1	0	0	0	0	0	3
IRELAND	1	1	2	1	0	0	0	4
ITALY	1	40	13	2	26	56	32	33
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	37	914	744	630	139	590	714	900
POLAND	0	0	0	0	0	4	16	9
PORTUGAL	0	3	2	0	0	0	0	0
ROMANIA	0	0	0	0	0	24	20	47
SLOVAKIA	0	0	0	0	0	1	3	3
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	97	430	659	249	338	132	330	551
SWEDEN	18	1	2	4	3	4	4	3
UNITED KINGDOM	7	18	5	23	25	27	32	2
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	2	8	24	1	16	2	4	0
BELGIUM (and LUXBG -> 1998)	25	0	22	0	0	1	0	42
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	3	19	5	6	5	3	8	2
DENMARK	0	0	0	3	6	26	0	1
ESTONIA	0	0	0	3	3	0	3	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	91	9	13	6	3	94	20	27
GERMANY (incl DD from 1991)	28	424	344	38	29	41	34	35
GREECE	0	8	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	1	28	12	130	14	5	14	1
LATVIA	0	0	0	0	0	11	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	58	236	81	164	26	95	161	92
POLAND	0	0	0	0	0	0	3	34
PORTUGAL	0	0	0	50	0	0	0	0
ROMANIA	40	0	0	0	0	0	5	3
SLOVENIA	1	1	1	1	16	7	1	0
SPAIN	5	15	142	45	82	202	533	378
SWEDEN	2	0	23	0	0	0	1	0
UNITED KINGDOM	3	1	17	6	0	1	185	82
SLOVAKIA	0	0	0	0	0	0	0	0
EU27_extra import	257	35	106	86	143	345	272	254
EU27_extra export	160	116	244	218	55	237	320	126
EU27_intra import	148	1475	1546	896	486	863	1139	1538
EU27_intra export	98	662	458	236	146	251	653	571

2825 90 50 - MERCURY OXIDES.								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG ->1998)	0	0	0	0	0	0	0	0
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
GERMANY (incl DD from 1991)	8	0	0	0	0	0	0	0
DENMARK	0	0	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
SPAIN	0	2	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	1	2	0	0	0	0	0	1
UNITED KINGDOM	1	1	0	0	1	0	0	0
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	56	8	0	0	0	0	0	0
ITALY	0	0	0	0	0	0	1	2
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
LATVIA	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	0	36	5	0	0	0	0	0
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	1	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SWEDEN	0	0	0	0	0	0	1	0
SLOVENIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
	Export (tonnes)							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG ->1998)	0	0	0	8	20	0	0	0
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
GERMANY (incl DD from 1991)	8	1	1	1	1	3	1	1
DENMARK	0	0	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
SPAIN	9	3	3	2	1	2	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	0	2	0	0	1	0	0	0
UNITED KINGDOM	0	0	0	0	0	0	0	1
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	0	1	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
LATVIA	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	0	24	0	0	0	0	0	0
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	0	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SWEDEN	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
EU27_extra import	1	2	0	0	0	0	0	1
EU27_extra export	3	4	4	10	2	3	1	2
EU27_intra import	66	47	6	1	1	1	2	2
EU27_intra export	14	26	0	1	21	2	0	0

2843 90 10 - AMALGAMS OF PRECIOUS METALS.								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	3	5	0	0	0	0	5	0
BELGIUM (and LUXBG -> 1998)	1	5	1	16	2	10	1	2
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
DENMARK	0	0	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	1	1	1
FINLAND	0	0	0	0	0	0	0	0
FRANCE	2	4	1	1	1	2	3	2
GERMANY (incl DD from 1991)	1	1	1	0	1	1	2	3
GREECE	0	7	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	1	1	0	1	1	0	1	1
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	4	2	0	1	1	34	12	2
POLAND	0	0	0	0	0	5	7	4
PORTUGAL	0	1	1	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	1	3	2	0	6	1	1	0
SWEDEN	0	0	0	0	1	0	0	0
UNITED KINGDOM	1	0	5	3	4	4	8	11
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	0	0	0	12	0	0	0	0
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
DENMARK	0	0	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	0	1	3	1	0	2	3	5
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	1
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	0	1	1	1	0	1	0	0
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	2	1	1	1	2	34	35	19
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	0	0	0	0	24	42	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	0	0	0	0	0	0	0	0
SWEDEN	4	5	0	0	1	0	0	1
UNITED KINGDOM	0	0	0	1	1	0	0	1
EU27_extra import	6	7	1	3	2	2	8	4
EU27_extra export	1	2	1	0	0	1	8	16
EU27_intra import	11	25	15	22	15	57	33	22
EU27_intra export	6	7	5	16	27	79	30	11

8506 10 15 - MANGANESE DIOXIDE CELLS AND BATTERIES, ALKALINE, IN THE FORM OF BUTTON CELLS (EXCL. SPENT).								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	12	2	2	1	1	4	2	8
BELGIUM (and LUXBG -> 1998)	44	182	10	52	44	94	77	26
BULGARIA	6	8	1	3	4	4	2	1
CYPRUS	0	0	0	0	0	1	1	0
CZECH REPUBLIC (CS->1992)	20	19	36	21	27	7	8	13
DENMARK	12	9	6	3	3	3	6	2
ESTONIA	1	5	0	0	0	5	7	1
FINLAND	3	12	21	8	6	5	4	11
FRANCE	133	85	90	74	130	178	81	23
GERMANY (incl DD from 1991)	256	250	86	205	135	98	169	143
GREECE	22	5	80	13	12	13	9	7
HUNGARY	19	29	13	10	16	27	164	69
IRELAND	4	3	3	6	5	3	1	2
ITALY	70	36	60	96	61	79	42	17
LATVIA	1	1	1	0	0	1	1	0
LITHUANIA	3	2	3	1	3	2	0	0
LUXEMBOURG	0	1	2	2	1	11	11	5
MALTA	0	0	0	0	0	1	1	3
NETHERLANDS	76	41	251	95	146	45	407	10
POLAND	0	0	0	0	0	14	18	17
PORTUGAL	0	1	5	4	3	4	11	30
ROMANIA	11	10	14	20	8	7	3	11
SLOVAKIA	0	0	0	0	0	2	2	3
SLOVENIA	2	4	4	3	3	2	0	0
SPAIN	37	84	51	67	114	65	277	19
SWEDEN	35	89	83	12	5	6	6	3
UNITED KINGDOM	432	112	155	194	773	241	174	199
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	2	8	0	0	1	0	0	0
BELGIUM (and LUXBG -> 1998)	66	178	47	65	51	53	62	7
BULGARIA	0	0	0	0	0	0	0	1
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	5	5	1	3	0
DENMARK	3	1	1	1	1	1	1	1
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	30	21	34	9	9	2	1	4
GERMANY (incl DD from 1991)	152	188	104	71	60	52	51	68
GREECE	0	0	4	12	3	4	0	1
HUNGARY	0	0	1	3	0	1	0	5
IRELAND	0	0	0	0	0	0	0	0
ITALY	28	6	0	1	4	1	4	28
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	1	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	14	8	30	23	11	45	43	1
POLAND	0	0	0	0	0	0	1	4
PORTUGAL	0	0	0	0	0	1	4	1
ROMANIA	0	0	0	0	0	0	0	1
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	2	0	0
SPAIN	6	7	9	6	3	8	8	0
SWEDEN	70	22	8	6	4	4	3	2
UNITED KINGDOM	24	191	116	64	61	29	26	23
EU27_extra import	601	727	548	564	678	603	832	440
EU27_extra export	132	186	66	35	31	22	17	59
EU27_intra import	615	292	461	339	840	319	651	181
EU27_intra export	269	444	290	233	184	181	191	87

8506 30 10 - MERCURIC OXIDE CELLS AND BATTERIES, IN THE FORM OF CYLINDRICAL CELLS (EXCL. SPENT).								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	0	1	0	2	0	0	0	0
BELGIUM (and LUXBG -> 1998)	2	1	3	1	7	23	16	0
BULGARIA	87	50	1	1	0	0	0	1
CYPRUS	0	0	0	0	0	2	0	0
CZECH REPUBLIC (CS->1992)	3	0	0	3	12	2	0	0
DENMARK	7	14	41	6	9	6	0	0
ESTONIA	1	1	0	0	0	1	1	0
FINLAND	0	16	0	0	0	0	0	1
FRANCE	50	48	28	1	47	29	52	23
GERMANY (incl DD from 1991)	2	2	2	3	22	2	1	4
GREECE	111	37	80	966	175	51	21	31
HUNGARY	0	0	0	0	0	1	0	1
IRELAND	0	0	1	1	0	0	0	0
ITALY	76	2	1	2	2	0	3	0
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	2	0	0	0	0	0	23
LUXEMBOURG	0	0	0	0	0	9	4	1
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	16	12	9	6	10	28	19	6
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	250	130	1	1	4	1	1	1
ROMANIA	0	3	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	82	32	2	28	11	2	2	0
SWEDEN	17	2	2	3	0	0	0	5
UNITED KINGDOM	102	27	101	69	214	77	113	79
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	1	0	0	0	0	0	0	0
BULGARIA	0	0	0	0	1	0	2	1
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
DENMARK	2	2	2	3	0	0	0	0
ESTONIA	0	0	0	0	1	2	4	1
FINLAND	2	1	0	0	1	1	0	0
FRANCE	2	4	0	7	10	14	13	0
GERMANY (incl DD from 1991)	5	0	0	0	0	1	0	0
GREECE	251	344	94	170	46	2	2	3
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	2	11	5	38	59	42	44	12
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	9	7	16	5	7	18	3	0
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	12	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	101	22	17	23	3	3	2	0
SWEDEN	88	1	17	3	0	0	0	0
UNITED KINGDOM	7	4	2	10	6	1	2	0
EU27_extra import	284	184	253	171	454	165	154	163
EU27_extra export	208	279	84	143	29	15	34	7
EU27_intra import	524	195	18	923	59	71	79	13
EU27_intra export	273	117	71	117	104	68	37	11

8506 30 30 - MERCURIC OXIDE CELLS AND BATTERIES, IN THE FORM OF BUTTON CELLS (EXCL. SPENT).								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	0	0	0	0	0	0	0	0
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	1	0	0	0	0	0	0	0
DENMARK	1	4	1	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	1	0	0	0	1	1	1	0
GERMANY (incl DD from 1991)	2	19	0	0	0	0	1	0
GREECE	3	0	1	3	50	0	0	0
HUNGARY	1	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	1	1	0	0	0	0	1	0
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	0	0	0	0	0	1	1	0
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	2	1	6	11	11	11	8	4
ROMANIA	0	1	0	0	0	1	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	194	36	1	0	0	0	8	0
SWEDEN	1	0	0	0	0	1	0	0
UNITED KINGDOM	3	1	5	2	0	0	0	0
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	0	0	1	0	3	2	1	0
BULGARIA	0	0	0	0	3	3	0	1
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
DENMARK	0	0	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	0	0	0	0	0	1	0	0
GERMANY (incl DD from 1991)	5	0	0	0	0	0	0	0
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	29	98	58	65	24	15	44	1
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	2	7	63	4	2	10	0	0
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	0	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	2	0	0	0	0	0
SPAIN	13	15	0	0	0	8	5	0
SWEDEN	1	0	0	0	0	0	0	0
UNITED KINGDOM	19	0	0	1	0	0	1	5
EU27_extra import	4	4	6	3	1	2	3	1
EU27_extra export	19	7	63	4	5	17	2	6
EU27_intra import	205	60	9	14	61	13	19	4
EU27_intra export	50	113	61	66	27	21	49	0

8506 30 90 - MERCURIC OXIDE CELLS AND BATTERIES (EXCL. SPENT, CYLINDRICAL OR BUTTON CELLS).								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	6	2	1	10	2	0	0	0
BELGIUM (and LUXBG -> 1998)	67	80	108	154	90	119	145	0
BULGARIA	269	412	247	233	171	191	197	206
CYPRUS	0	0	0	0	0	1	0	2
CZECH REPUBLIC (CS->1992)	0	0	1	0	0	0	0	0
DENMARK	2	71	3	0	0	5	2	14
ESTONIA	0	2	0	0	0	1	0	0
FINLAND	10	9	7	3	4	4	3	2
FRANCE	20	4	1	1	15	28	33	54
GERMANY (incl DD from 1991)	3	6	11	1	0	1	7	11
GREECE	1	0	0	0	0	1	1	16
HUNGARY	0	4	0	0	0	0	0	0
IRELAND	1	5	1	3	0	0	1	1
ITALY	53	98	63	64	134	80	109	105
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	2	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	5	2	13	4	0	8	1	1
POLAND	0	0	0	0	0	0	0	0
PORTUGAL	0	0	0	0	0	0	0	1
ROMANIA	0	0	0	0	0	0	0	1
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	572	3	7	0	13	2	8	7
SWEDEN	0	0	0	4	0	0	0	0
UNITED KINGDOM	225	249	193	55	185	78	14	53

	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	0	0	0	0
BELGIUM (and LUXBG -> 1998)	3	8	2	7	3	0	11	0
BULGARIA	44	57	54	60	22	7	7	3
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	0	0	0	0
DENMARK	0	1	4	0	0	0	2	6
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	16	1	0	0	0	1	0	2
GERMANY (incl DD from 1991)	21	53	41	1	0	0	0	1
GREECE	2	2	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	1	0	0	0	0
ITALY	31	12	25	34	47	14	21	2
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	1
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	77	112	115	130	85	120	137	0
POLAND	0	0	0	0	0	1	11	7
PORTUGAL	0	0	0	0	0	1	0	5
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	82	2	10	0	0	0	0	0
SWEDEN	1	0	0	0	0	4	0	0
UNITED KINGDOM	7	2	4	10	4	0	3	1
EU27_extra import	463	745	500	353	493	334	320	471
EU27_extra export	71	119	69	77	32	13	14	16
EU27_intra import	772	211	160	186	125	187	204	2
EU27_intra export	214	132	186	165	129	135	178	10

8506 40 30 - SILVER OXIDE CELLS AND BATTERIES, IN THE FORM OF BUTTON CELLS (EXCL. SPENT)								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	2	3	3	3	3	16	1	1
BELGIUM (and LUXBG -> 1998)	18	12	75	293	23	114	52	42
BULGARIA	2	0	0	0	1	0	0	0
CYPRUS	0	0	0	0	0	19	2	1
CZECH REPUBLIC (CS->1992)	9	9	4	15	37	13	7	21
DENMARK	3	2	2	1	1	1	1	1
ESTONIA	1	0	0	0	0	5	6	0
FINLAND	9	5	24	7	15	10	9	8
FRANCE	114	104	70	52	100	38	37	20
GERMANY (incl DD from 1991)	38	42	61	36	37	36	39	31
GREECE	5	2	2	1	0	14	4	0
HUNGARY	3	3	3	7	17	38	4	0
IRELAND	4	1	4	2	1	1	1	2
ITALY	94	67	108	108	123	119	21	8
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	1	0	0	0	0	1	0	0
MALTA	0	0	0	0	0	1	3	2
NETHERLANDS	132	18	103	28	41	35	24	37
POLAND	0	0	0	0	0	3	3	4
PORTUGAL	27	9	9	9	9	7	2	8
ROMANIA	0	0	1	5	4	5	3	4
SLOVAKIA	0	0	0	0	0	4	0	0
SLOVENIA	3	3	2	3	2	1	146	60
SPAIN	11	31	244	78	69	34	39	15
SWEDEN	8	16	21	22	22	10	7	13
UNITED KINGDOM	289	151	64	44	196	43	36	57
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	5	2	1	2	0	0	0	4
BELGIUM (and LUXBG -> 1998)	40	44	24	33	61	45	43	1
BULGARIA	0	0	0	0	1	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	0	0	0	4	3	2	44
DENMARK	1	1	0	0	0	0	0	0
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	92	39	30	20	6	5	2	1
GERMANY (incl DD from 1991)	150	152	104	80	75	64	56	68
GREECE	0	0	0	0	0	0	0	0
HUNGARY	1	0	0	0	0	1	0	0
IRELAND	1	2	2	1	0	0	0	0
ITALY	12	16	6	7	6	4	4	0
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	84	24	59	21	18	23	17	2
POLAND	0	0	0	0	0	0	0	1
PORTUGAL	1	1	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	1	2	1	0	1	2	1	0
SWEDEN	99	38	2	4	3	3	3	5
UNITED KINGDOM	148	305	673	133	47	35	21	17
EU27_extra import	293	153	256	421	296	246	157	208
EU27_extra export	336	162	78	61	57	47	37	83
EU27_intra import	483	332	549	300	419	321	290	125
EU27_intra export	299	464	825	242	165	137	112	58

8506 60 30 - AIR-ZINC CELLS AND BATTERIES, IN THE FORM OF BUTTON CELLS (EXCL. SPENT)								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	3	6	4	1	3	16	11	10
BELGIUM (and LUXBG -> 1998)	80	29	11	92	78	138	122	19
BULGARIA	0	0	0	0	1	2	1	0
CYPRUS	0	0	0	0	0	1	2	2
CZECH REPUBLIC (CS->1992)	3	15	4	5	8	5	7	0
DENMARK	86	87	14	32	1409	1718	21	10
ESTONIA	0	0	0	0	0	1	2	0
FINLAND	3	4	4	9	8	6	4	2
FRANCE	36	46	49	36	34	43	49	1
GERMANY (incl DD from 1991)	29	26	41	32	166	124	105	100
GREECE	2	1	0	0	7	5	7	3
HUNGARY	6	7	9	9	10	4	19	6
IRELAND	1	0	1	3	3	5	4	4
ITALY	9	4	5	5	27	29	27	29
LATVIA	0	0	0	0	0	1	1	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	1	0
MALTA	0	0	0	0	0	0	2	1
NETHERLANDS	24	15	23	15	344	670	72	5
POLAND	0	0	0	0	0	12	9	4
PORTUGAL	0	1	0	1	0	0	0	1
ROMANIA	0	0	1	1	1	1	0	1
SLOVAKIA	0	0	0	0	0	0	2	0
SLOVENIA	2	1	1	1	1	0	1	1
SPAIN	5	82	82	45	43	26	1121	1
SWEDEN	6	12	6	7	8	6	8	8
UNITED KINGDOM	84	215	76	44	393	81	54	51
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	0	0	0	0	1	0	0	0
BELGIUM (and LUXBG -> 1998)	117	109	94	93	80	92	73	13
BULGARIA	0	0	0	0	0	0	0	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	0	8	0	0	0	0	1	0
DENMARK	17	14	9	6	6	6	5	4
ESTONIA	0	0	0	0	0	0	0	0
FINLAND	0	0	0	0	0	0	0	0
FRANCE	10	10	8	6	1	1	1	3
GERMANY (incl DD from 1991)	89	149	125	134	118	136	172	241
GREECE	0	0	0	0	0	0	0	0
HUNGARY	0	0	0	0	0	0	0	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	12	17	2	2	60	160	0	0
LATVIA	0	0	0	0	0	0	1	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	1	1	0	1	7	4	2	1
POLAND	0	0	0	0	0	1	1	0
PORTUGAL	0	0	0	0	0	0	0	0
ROMANIA	0	0	0	0	0	0	0	0
SLOVAKIA	0	0	0	0	0	0	0	0
SLOVENIA	0	0	0	0	0	0	0	0
SPAIN	0	217	1	1	2	2	1	0
SWEDEN	4	3	1	1	0	1	1	1
UNITED KINGDOM	969	265	343	350	2981	2098	351	256
EU27_extra import	59	61	52	66	57	129	152	74
EU27_extra export	721	94	89	103	101	110	135	157
EU27_intra import	328	519	284	278	2499	2765	1497	186
EU27_intra export	500	713	494	491	3155	2390	472	363

8539 31 10 - DISCHARGE LAMPS, FLUORESCENT, HOT CATHODE, WITH DOUBLE ENDED CAP.								
Data from COMEXT database	Import (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	1454	1173	939	1142	1315	987	1505	1335
BELGIUM (and LUXBG -> 1998)	27	112	29	25	18	6	170	138
BULGARIA	117	177	255	293	401	457	494	529
CYPRUS	0	0	0	0	0	23	49	21
CZECH REPUBLIC (CS->1992)	1452	1619	1679	1706	1775	1993	2379	138
DENMARK	114	99	61	13	30	9	181	749
ESTONIA	96	121	112	135	145	84	59	156
FINLAND	1604	1408	1260	1051	1072	1104	1096	1026
FRANCE	9576	9434	13941	8651	9394	8777	9112	756
GERMANY (incl DD from 1991)	5908	9779	12528	7930	8215	7412	8520	11348
GREECE	980	1099	30270	1080	920	816	735	982
HUNGARY	726	951	800	999	860	1137	106	112
IRELAND	0	0	0	0	0	0	0	0
ITALY	6269	6588	6834	7071	6036	5922	6395	1720
LATVIA	205	183	195	184	192	52	12	18
LITHUANIA	185	238	233	262	276	82	13	308
LUXEMBOURG	57	83	120	97	59	57	58	52
MALTA	0	0	0	0	0	19	26	49
NETHERLANDS	1824	1425	1966	2331	1437	386	1684	1836
POLAND	0	0	0	0	0	2423	2525	4596
PORTUGAL	1	2	11	9	14	18	30	31
ROMANIA	641	861	970	954	1065	1105	1045	1352
SLOVAKIA	0	0	0	0	0	413	471	449
SLOVENIA	169	206	202	255	254	219	97	272
SPAIN	724	1049	814	0	408	627	313	309
SWEDEN	2376	2735	2697	2480	2107	2270	2205	1916
UNITED KINGDOM	5358	4954	8267	75362	43514	9130	7006	7603
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	281	260	232	207	207	211	215	198
BELGIUM (and LUXBG -> 1998)	8	34	2	1	4	2	43	19
BULGARIA	31	0	12	4	8	34	30	28
CYPRUS	0	0	0	0	0	0	1	0
CZECH REPUBLIC (CS->1992)	573	599	704	671	1070	1145	1160	3
DENMARK	444	544	456	174	21	20	18	25
ESTONIA	2	4	7	4	8	6	7	6
FINLAND	60	27	26	24	23	23	19	25
FRANCE	16323	16195	18067	20817	15782	15024	15539	1301
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	17	10	20	8	6	14	11	8
HUNGARY	7074	10874	10034	11731	14432	12766	10741	9873
IRELAND	0	0	0	0	0	0	0	0
ITALY	4004	595	367	247	467	863	1325	257
LATVIA	2	1	1	2	1	0	0	0
LITHUANIA	1	1	1	1	1	2	5	12
LUXEMBOURG	0	1	0	19	24	49	39	11
MALTA	0	0	0	0	0	0	0	1
NETHERLANDS	7390	8311	9060	9732	6984	6709	6767	6645
POLAND	0	0	0	0	0	8618	10326	13720
PORTUGAL	17	25	56	27	25	26	12	21
ROMANIA	2	7	83	16	15	30	15	54
SLOVAKIA	0	0	0	0	0	21	65	34
SLOVENIA	7	9	5	10	9	15	13	16
SPAIN	135	218	157	0	58	69	10	36
SWEDEN	1136	1293	1208	1082	1024	1108	1610	2476
UNITED KINGDOM	4826	6974	2814	3742	3719	2158	1227	688
EU27_extra import	2743	3482	3517	2579	3081	3232	5938	7175
EU27_extra export	17416	22441	21770	23467	20548	24067	26176	26759
EU27_intra import	38896	43160	83846	114247	81563	42294	40348	30627
EU27_intra export	30745	33055	31838	35866	32033	24844	23021	8699

8539 31 90 - DISCHARGE LAMPS, FLUORESCENT, HOT CATHODE (EXCL. WITH DOUBLE ENDED CAP).								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	280	305	230	246	301	397	554	392
BELGIUM (and LUXBG -> 1998)	258	125	134	100	206	481	935	850
BULGARIA	66	32	35	75	82	99	124	102
CYPRUS	0	0	0	0	0	90	164	109
CZECH REPUBLIC (CS->1992)	162	168	246	284	317	342	413	142
DENMARK	217	262	267	158	229	174	123	293
ESTONIA	16	21	17	48	21	45	44	47
FINLAND	508	569	464	478	650	771	784	592
FRANCE	4499	5269	8416	9413	8350	8233	7765	1400
GERMANY (incl DD from 1991)	4912	6635	6347	5756	5531	6845	8571	9100
GREECE	548	506	29815	450	511	717	816	836
HUNGARY	300	252	267	248	265	565	788	445
IRELAND	0	0	0	0	9	0	0	0
ITALY	3249	2999	2667	2803	3220	3994	5395	3531
LATVIA	24	19	30	29	36	49	3	6
LITHUANIA	22	21	16	33	39	27	26	69
LUXEMBOURG	13	8	13	21	13	11	15	27
MALTA	0	0	0	0	0	12	30	50
NETHERLANDS	2452	2321	2220	1686	1740	1166	730	846
POLAND	0	0	0	0	0	2016	5038	5196
PORTUGAL	9	10	13	20	60	48	92	113
ROMANIA	82	125	161	211	176	237	331	472
SLOVAKIA	0	0	0	0	0	145	106	123
SLOVENIA	121	105	68	70	86	96	65	229
SPAIN	229	425	176	0	737	1331	1584	2005
SWEDEN	1593	1244	1021	946	923	1029	1145	1029
UNITED KINGDOM	42873	4790	3799	18923	11042	5023	5671	5862
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	135	95	66	70	176	77	102	103
BELGIUM (and LUXBG -> 1998)	400	516	553	400	240	263	220	201
BULGARIA	0	1	5	4	3	3	6	6
CYPRUS	0	0	0	0	0	2	22	1
CZECH REPUBLIC (CS->1992)	104	49	13	18	19	65	29	4
DENMARK	58	74	62	23	7	5	8	15
ESTONIA	1	1	1	1	1	13	20	1
FINLAND	63	65	62	53	74	58	82	83
FRANCE	3093	2922	3212	10006	4658	5471	4833	145
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	74	126	97	139	141	113	88	110
HUNGARY	2405	3057	3379	2754	2709	2212	1461	1377
IRELAND	0	0	0	0	0	0	0	0
ITALY	893	5191	4823	4857	4349	3407	3556	804
LATVIA	1	0	8	0	2	1	0	0
LITHUANIA	21	2	2	10	12	10	2	5
LUXEMBOURG	1	1	0	0	0	0	0	7
MALTA	0	0	0	0	0	0	0	1
NETHERLANDS	1750	1720	1465	1536	1365	1041	815	1130
POLAND	0	0	0	0	0	2328	4324	7428
PORTUGAL	14	17	16	23	25	11	16	45
ROMANIA	4	3	3	2	3	27	57	48
SLOVAKIA	0	0	0	0	0	76	37	49
SLOVENIA	7	10	15	11	7	11	31	85
SPAIN	70	68	71	0	46	79	36	60
SWEDEN	502	556	592	466	483	407	415	444
UNITED KINGDOM	1286	3663	1274	3862	4660	4671	2146	1241
EU27_extra import	5272	6680	6516	6293	9201	13390	20196	22200
EU27_extra export	4999	6181	5895	5195	5920	5726	4249	4945
EU27_intra import	57874	20192	51069	36708	26488	20551	21116	11665
EU27_intra export	9508	15549	13532	22751	16579	14623	14056	8445

8539 32 10 - MERCURY VAPOUR LAMPS								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	11	6	1	5	5	3	4	3
BELGIUM (and LUXBG -> 1998)	26	179	219	674	52	304	207	335
BULGARIA	31	19	25	21	23	21	17	23
CYPRUS	0	0	0	0	0	0	1	1
CZECH REPUBLIC (CS->1992)	100	24	16	17	23	21	48	7
DENMARK	0	0	0	0	0	0	0	6
ESTONIA	8	8	6	7	7	6	4	3
FINLAND	71	65	52	38	47	55	58	46
FRANCE	563	685	606	457	393	461	458	11
GERMANY (incl DD from 1991)	515	456	483	236	263	320	588	536
GREECE	39	31	2220	28	24	38	34	31
HUNGARY	49	20	15	13	6	16	15	20
IRELAND	0	0	0	0	0	0	0	0
ITALY	221	176	134	147	152	172	170	33
LATVIA	67	45	46	25	22	8	1	1
LITHUANIA	11	9	10	9	8	5	3	12
LUXEMBOURG	1	4	2	2	1	4	3	2
MALTA	0	0	0	0	0	0	1	1
NETHERLANDS	35	12	3	6	11	8	7	26
POLAND	0	0	0	0	0	154	441	707
PORTUGAL	0	0	0	0	0	0	0	0
ROMANIA	26	27	36	45	58	78	85	94
SLOVAKIA	0	0	0	0	0	12	11	11
SLOVENIA	18	17	12	13	13	12	5	7
SPAIN	32	96	15	0	1	9	1	2
SWEDEN	140	120	87	60	66	84	126	67
UNITED KINGDOM	26	32	41	187	133	191	138	71
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	8	3	0	2	0	0	3	0
BELGIUM (and LUXBG -> 1998)	34	71	108	139	97	42	2	1
BULGARIA	1	0	1	0	0	0	0	1
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	28	23	22	14	4	4	11	4
DENMARK	9	11	8	6	0	0	0	0
ESTONIA	3	0	0	0	0	0	0	0
FINLAND	4	1	0	0	0	0	0	0
FRANCE	369	402	401	298	352	360	341	4
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	0	0	1	2	0	1	0	0
HUNGARY	519	684	484	491	445	213	283	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	21	20	30	8	1	5	30	8
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	41	42	46	19	21	0	0	0
LUXEMBOURG	0	0	0	0	0	1	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	141	279	124	98	413	109	30	13
POLAND	0	0	0	0	0	173	282	427
PORTUGAL	0	0	0	0	0	1	0	1
ROMANIA	67	71	51	54	41	19	20	9
SLOVAKIA	0	0	0	0	0	8	7	11
SLOVENIA	3	3	3	4	3	3	1	2
SPAIN	38	4	1	0	1	2	0	0
SWEDEN	45	38	37	23	27	20	19	8
UNITED KINGDOM	52	196	26	12	19	29	36	26
EU27_extra import	277	594	662	927	393	711	997	1065
EU27_extra export	631	1030	644	590	838	510	585	317
EU27_intra import	1820	1537	3481	1193	1041	1270	1430	990
EU27_intra export	909	995	834	1011	710	480	482	197

8539 32 50 - SODIUM VAPOUR LAMPS.								
Data from COMEXT database	**Import (tonnes)**							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	12	7	5	9	13	8	22	10
BELGIUM (and LUXBG -> 1998)	36	77	88	131	4	68	126	76
BULGARIA	15	9	10	11	13	10	11	13
CYPRUS	0	0	0	0	0	0	4	3
CZECH REPUBLIC (CS->1992)	38	33	50	52	60	46	53	8
DENMARK	0	0	0	26	4	141	3	19
ESTONIA	2	6	6	5	6	4	5	4
FINLAND	109	111	81	48	57	65	70	62
FRANCE	774	916	1222	1110	1021	1055	991	17
GERMANY (incl DD from 1991)	446	450	451	513	572	696	733	884
GREECE	19	23	1868	17	18	23	21	26
HUNGARY	33	10	13	22	11	22	0	1
IRELAND	0	0	0	0	0	3	0	0
ITALY	447	306	280	256	236	286	306	70
LATVIA	6	5	6	5	4	1	0	0
LITHUANIA	4	3	6	5	7	2	10	19
LUXEMBOURG	4	9	4	4	2	1	2	4
MALTA	0	0	0	0	0	1	5	5
NETHERLANDS	3	1	6	6	13	5	1	2
POLAND	0	0	0	0	0	104	167	228
PORTUGAL	0	0	0	0	0	3	1	0
ROMANIA	9	11	9	12	6	8	12	16
SLOVAKIA	0	0	0	0	0	12	17	13
SLOVENIA	13	15	11	11	13	11	4	5
SPAIN	15	75	87	0	11	19	12	14
SWEDEN	188	138	106	112	118	91	85	79
UNITED KINGDOM	157	184	404	2123	4003	430	338	592
	Export (tonnes)							
	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	6	4	1	1	3	1	2	1
BELGIUM (and LUXBG -> 1998)	154	202	181	217	55	163	77	62
BULGARIA	0	0	0	0	0	0	3	1
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	45	29	26	21	7	8	10	1
DENMARK	32	47	28	6	0	0	0	3
ESTONIA	2	2	0	0	0	1	0	0
FINLAND	2	0	1	2	0	1	2	1
FRANCE	441	486	692	762	885	663	593	16
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	0	0	1	0	1	2	0	0
HUNGARY	409	592	644	624	602	239	321	0
IRELAND	0	0	0	0	0	0	0	0
ITALY	9	15	16	6	2	30	28	11
LATVIA	0	1	0	1	0	0	0	0
LITHUANIA	0	0	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	279	308	240	201	154	243	225	200
POLAND	0	0	0	0	0	110	179	192
PORTUGAL	0	0	0	0	0	1	1	3
ROMANIA	24	61	64	53	44	26	35	33
SLOVAKIA	0	0	0	0	0	55	51	482
SLOVENIA	1	1	1	1	1	1	1	0
SPAIN	15	3	5	0	2	2	7	1
SWEDEN	85	51	49	56	71	51	67	47
UNITED KINGDOM	643	622	669	522	689	644	667	693
EU27_extra import	84	130	249	373	349	554	517	481
EU27_extra export	610	924	869	790	773	910	948	567
EU27_intra import	2380	2400	4613	4277	6011	2560	2481	1688
EU27_intra export	1561	1556	1855	1843	1908	1329	1320	1181

8539 32 90 - METAL HALIDE LAMPS.								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	57	34	25	25	37	53	67	44
BELGIUM (and LUXBG -> 1998)	19	22	180	37	17	22	33	100
BULGARIA	5	1	2	4	7	13	12	12
CYPRUS	0	0	0	0	0	4	16	3
CZECH REPUBLIC (CS->1992)	6	11	14	18	28	33	49	0
DENMARK	0	0	0	0	0	0	1	15
ESTONIA	1	1	1	3	3	13	19	14
FINLAND	50	61	52	38	37	38	41	61
FRANCE	306	389	425	655	601	745	750	49
GERMANY (incl DD from 1991)	91	132	177	444	758	751	520	573
GREECE	47	36	562	71	73	105	126	64
HUNGARY	10	48	12	10	10	19	0	6
IRELAND	0	1	0	0	0	0	0	0
ITALY	203	279	307	497	493	437	490	102
LATVIA	1	6	2	3	5	2	0	0
LITHUANIA	2	2	3	5	5	1	0	76
LUXEMBOURG	2	0	1	2	7	1	0	0
MALTA	0	0	0	0	0	1	2	16
NETHERLANDS	27	25	38	77	46	45	72	63
POLAND	0	0	0	0	0	52	94	136
PORTUGAL	0	0	2	1	1	2	1	0
ROMANIA	4	10	5	18	9	25	27	35
SLOVAKIA	0	0	0	0	0	13	20	67
SLOVENIA	19	21	25	26	24	25	13	31
SPAIN	17	29	38	0	2	24	99	36
SWEDEN	176	79	99	80	116	151	88	93
UNITED KINGDOM	166	94	223	1146	683	1125	435	537
	Export (tonnes)							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	19	11	8	9	10	11	7	4
BELGIUM (and LUXBG -> 1998)	87	169	327	404	143	347	584	505
BULGARIA	1	0	0	0	0	1	6	0
CYPRUS	0	0	0	0	0	0	0	0
CZECH REPUBLIC (CS->1992)	1	3	2	0	1	8	61	1
DENMARK	0	0	4	8	4	0	1	4
ESTONIA	0	0	0	0	0	9	4	0
FINLAND	14	15	13	20	16	16	17	20
FRANCE	222	216	449	485	599	673	640	90
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	0	0	1	0	0	2	0	2
HUNGARY	101	176	194	187	219	250	243	295
IRELAND	0	0	0	0	0	0	0	0
ITALY	18	37	34	32	28	42	51	11
LATVIA	0	0	0	0	0	0	0	0
LITHUANIA	0	2	0	0	0	0	0	0
LUXEMBOURG	0	0	0	0	0	0	0	0
MALTA	0	0	0	0	0	0	0	0
NETHERLANDS	476	107	52	48	18	68	198	267
POLAND	0	0	0	0	0	40	91	147
PORTUGAL	1	0	1	0	6	5	4	18
ROMANIA	10	14	13	23	24	26	47	26
SLOVAKIA	0	0	0	0	0	5	35	184
SLOVENIA	3	2	1	4	7	4	5	8
SPAIN	26	2	12	0	2	1	5	29
SWEDEN	63	28	30	25	24	31	38	34
UNITED KINGDOM	125	149	116	138	157	155	144	170
EU27_extra import	307	372	631	780	773	903	920	1029
EU27_extra export	329	516	797	745	513	915	1352	1392
EU27_intra import	960	971	1612	2455	2268	2798	2054	1103
EU27_intra export	841	426	469	663	792	781	827	422

8539 39 00 - DISCHARGE LAMPS (EXCL. FLOURESCENT, HOT CATHODE LAMPS, ULTRAVIOLET LAMPS, AND MORE).								
Data from COMEXT database	**Import (tonnes)**							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	24	33	42	41	44	30	18	24
BELGIUM (and LUXBG -> 1998)	9	21	21	22	26	25	31	68
BULGARIA	4	3	8	11	11	12	15	16
CYPRUS	0	0	0	0	0	32	56	31
CZECH REPUBLIC (CS->1992)	223	220	147	198	474	175	108	11
DENMARK	9	12	77	48	2	14	2	8
ESTONIA	2	2	4	2	1	6	13	141
FINLAND	30	15	21	12	21	26	20	22
FRANCE	189	231	447	483	294	292	361	86
GERMANY (incl DD from 1991)	406	437	378	262	264	221	171	306
GREECE	57	79	1111	63	88	49	60	403
HUNGARY	50	59	60	51	42	36	18	2
IRELAND	0	0	2	0	0	0	0	0
ITALY	767	724	797	510	646	344	583	276
LATVIA	2	3	11	3	15	8	7	8
LITHUANIA	1	0	2	2	3	48	18	12
LUXEMBOURG	6	1	5	9	10	2	3	2
MALTA	0	0	0	0	0	4	7	1
NETHERLANDS	197	169	335	360	403	156	78	79
POLAND	0	0	0	0	0	106	207	34
PORTUGAL	7	3	5	1	3	5	4	12
ROMANIA	34	31	51	107	64	76	93	113
SLOVAKIA	0	0	0	0	0	18	8	16
SLOVENIA	17	20	18	18	24	29	12	16
SPAIN	147	219	90	0	209	142	101	151
SWEDEN	51	40	35	52	48	43	18	57
UNITED KINGDOM	706	695	594	990	1275	1041	1098	10825
	Export (tonnes)							
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
AUSTRIA	14	17	23	21	26	20	15	14
BELGIUM (and LUXBG -> 1998)	14	36	47	111	73	186	236	144
BULGARIA	0	4	4	8	0	1	0	1
CYPRUS	0	0	0	0	0	3	9	0
CZECH REPUBLIC (CS->1992)	18	9	4	14	11	27	33	1
DENMARK	6	5	7	4	1	0	0	6
ESTONIA	0	1	1	1	0	0	0	0
FINLAND	3	1	1	1	0	2	5	4
FRANCE	152	192	408	445	333	288	339	74
GERMANY (incl DD from 1991)	0	0	0	0	0	0	0	0
GREECE	22	18	1	3	10	10	1	1
HUNGARY	44	74	69	41	41	25	10	12
IRELAND	0	0	0	0	0	0	0	0
ITALY	309	421	408	699	485	282	166	200
LATVIA	0	3	1	0	0	1	0	0
LITHUANIA	1	0	2	0	0	5	1	0
LUXEMBOURG	0	0	0	0	1	0	0	0
MALTA	0	0	0	0	0	0	2	0
NETHERLANDS	256	258	233	52	213	67	49	98
POLAND	0	0	0	0	0	28	46	103
PORTUGAL	13	15	30	17	13	34	30	39
ROMANIA	52	53	42	21	10	8	9	25
SLOVAKIA	0	0	0	0	0	4	60	52
SLOVENIA	4	3	3	2	3	1	0	0
SPAIN	25	72	64	0	45	21	42	32
SWEDEN	34	26	26	19	27	29	32	24
UNITED KINGDOM	733	788	339	129	786	99	161	99
EU27_extra import	1385	1349	1414	1672	2562	1600	1582	2062
EU27_extra export	863	1036	1155	1095	1728	740	782	802
EU27_intra import	1692	1728	2980	1698	1527	1338	1525	10658
EU27_intra export	876	1016	623	562	429	399	466	125

PRODCOM statistics 2004 -2006

All values and sold volumes are expressed in thousands. All confidential data and all national estimated data is suppressed.
(:C)=Confidential, (:CE)=Confidential Estimated, (:E)=Estimated.
Applied codes for countries and product groups in the tables:

a1	24131380 Mercury
a2	24134290 Inorganic compounds; amalgams (excluding distilled and conductivity water and water of similar purity
a3	31401111 Alkaline primary cells and primary batteries with a manganese dioxide cathode
a4	31401112 Alkaline primary cells and primary batteries with a manganese dioxide cathode
a5	31401113 Alkaline primary cells and primary batteries with a manganese dioxide cathode (excluding cylindrical or button cells)
a6	31401115 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode
a7	31401117 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode
a8	31401119 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode (excluding cylindrical or button cells)
a9	31401123 Primary cells and primary batteries with a mercuric oxide cathode
a10	31401125 Primary cells and primary batteries with a mercuric oxide cathode
a11	31401127 Primary cells and primary batteries with a mercuric oxide cathode (excluding cylindrical or button cells)
a12	31401133 Primary cells and primary batteries with a silver oxide cathode
a13	31401135 Primary cells and primary batteries with a silver oxide cathode
a14	31401137 Primary cells and primary batteries with a silver oxide cathode (excluding cylindrical or button cells)
a15	31401151 Lithium primary cells and primary batteries
a16	31401152 Lithium primary cells and primary batteries
a17	31401153 Lithium primary cells and batteries (excluding cylindrical or button cells)
a18	31401155 Air-zinc primary cells and primary batteries
a19	31401156 Air-zinc primary cells and primary batteries
a20	31401158 Air-zinc primary cells and primary batteries (excluding cylindrical or button cells)
a21	31401173 Other primary cells and batteries
a22	31401175 Other primary cells and batteries
a23	31401179 Other primary cells and batteries
a24	31501510 Fluorescent hot cathode discharge lamps
a25	31501530 Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps
a26	31501553 Mercury vapour discharge lamps (excluding ultraviolet lamps
a27	31501556 Sodium vapour discharge lamps other than ultraviolet lamps
a28	31501559 Discharge lamps (excluding fluorescent hot cathode lamps
a29	31501570 Ultraviolet or infrared lamps

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	id	Unit	2004	2005	2006
24131380 Mercury	**a1**	kg			
24134290 Inorganic compounds; amalgams (excluding distilled and conductivity water and water of similar purity	**a2**	kg	749,000 (EU25)	748,323	757,731
31401111 Alkaline primary cells and primary batteries with a manganese dioxide cathode	**a3**	p/st	3,470,114	3,720,244	3,521,312
31401112 Alkaline primary cells and primary batteries with a manganese dioxide cathode	**a4**	p/st			
31401113 Alkaline primary cells and primary batteries with a manganese dioxide cathode (excluding cylindrical or button cells)	**a5**	p/st			
31401115 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode	**a6**	p/st		90,094	26,798
31401117 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode	**a7**	p/st	0	0	0
31401119 Non-alkaline primary cells and primary batteries with a manganese dioxide cathode (excluding cylindrical or button cells)	**a8**	p/st	64,169		
31401123 Primary cells and primary batteries with a mercuric oxide cathode	**a9**	p/st			
31401125 Primary cells and primary batteries with a mercuric oxide cathode	**a10**	p/st	0	0	0
31401127 Primary cells and primary batteries with a mercuric oxide cathode (excluding cylindrical or button cells)	**a11**	p/st	0	0	0
31401133 Primary cells and primary batteries with a silver oxide cathode	**a12**	p/st			
31401135 Primary cells and primary batteries with a silver oxide cathode	**a13**	p/st			
31401137 Primary cells and primary batteries with a silver oxide cathode (excluding cylindrical or button cells)	**a14**	p/st			
31401151 Lithium primary cells and primary batteries	**a15**	p/st			
31401152 Lithium primary cells and primary batteries	**a16**	p/st			
31401153 Lithium primary cells and batteries (excluding cylindrical or button cells)	**a17**	p/st	5,451	4,525	64
31401155 Air-zinc primary cells and primary batteries	**a18**	p/st	5		1
31401156 Air-zinc primary cells and primary batteries	**a19**	p/st			
31401158 Air-zinc primary cells and primary batteries (excluding cylindrical or button cells)	**a20**	p/st			
31401173 Other primary cells and batteries	**a21**	p/st			
31401175 Other primary cells and batteries	**a22**	p/st			
31401179 Other primary cells and batteries	**a23**	p/st		2,291	
31501510 Fluorescent hot cathode discharge lamps	**a24**	p/st	441,522	463,561	552,194
31501530 Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps	**a25**	p/st		96,269	255,148
31501553 Mercury vapour discharge lamps (excluding ultraviolet lamps	**a26**	p/st		25,302	24,918
31501556 Sodium vapour discharge lamps other than ultraviolet lamps	**a27**	p/st			
31501559 Discharge lamps (excluding fluorescent hot cathode lamps	**a28**	p/st		79,918	23,752
31501570 Ultraviolet or infrared lamps	**a29**	p/st	53,939	52,847	57,434

Statistics on the production of manufactured goods Sold Volume ANNUAL 2004, by country

	Unit	EU 27	BE	BG	CZ	DK	DE	EE	IE	GR	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RU	SI	SK	FI	SE	UK	HR	IS	NO
a1	kg		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a2	kg		0	0	:C	0	:C	0	0	0	4643	:C	369623	0	0	0	0	0	0	0	0	350568	0	:C	:C	:C	0	0	:C	0	0	0
a3	p/st	3470114	:C	0	0	0	:C	0	:C	0	:C	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	1	0	:C	0	0	0
a4	p/st		0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a5	p/st		0	0	0	17207	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	:C	0	0	0
a6	p/st		0	:C	0	0	0	0	:C	:C	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a7	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a8	p/st	64169	:C	0	0	0	:C	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	:C	0	0	0
a9	p/st		0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a10	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a11	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a12	p/st		0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a13	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a14	p/st		0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a15	p/st		0	0	0	0	19209	0	:C	0	:C	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3377	0	0	CE
a16	p/st		0	0	0	0	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a17	p/st	5451	0	0	0	0	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a18	p/st	5	0	:C	0	0	0	0	:C	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a19	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a20	p/st		0	0	0	0	0	0	0	0	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a21	p/st		:C	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	0
a22	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CE	0	0	0	0	0	0	0	0	0	0
a23	p/st		:C	:C	0	0	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a24	p/st	441522	0	17	0	0	220129	0	0	0	:C	47359	:C	0	0	0	0	0	0	:C	0	0	0	0	:C	0	:C	:C	2961	:C	0	0
a25	p/st		:C	0	:C	0	:C	:C	:C	0	:C	:C	863	0	0	0	0	:C	0	:C	0	0	0	:C	0	0	0	0	:C	0	0	0
a26	p/st		:C	:C	:C	0	:C	0	0	0	0	:C	:C	0	0	0	0	0	0	:C	0	:C	:C	:C	0	:C	:C	0	:C	:C	0	0
a27	p/st		:C	:C	:C	0	5606	0	0	0	0	:C	192	0	0	0	0	0	0	:C	0	:C	0	:C	0	0	0	0	112	:C	0	:C
a28	p/st		:C	0	:C	0	2939	0	:C	0	:C	:C	470	0	0	0	0	:C	0	:E	0	:C	0	:C	0	:C	0	:E	:C	:C	0	0
a29	p/st	53939	:C	0	0	0	5634	0	0	0	0	:C	279	0	0	0	0	:C	0	:C	:C	:C	0	0	0	0	0	0	2690	0	0	0

Statistics on the production of manufactured goods Sold Volume ANNUAL 2005, by country

	Unit	EU 27	BE	BG	CZ	DK	DE	EE	IE	GR	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RU	SI	SK	FI	SE	UK	HR	IS	NO
a1	kg		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a2	kg	748323	0	0	:C	0	:C	0	0	0	7845	:C	374824	0	0	0	0	0	0	0	0	:C	0	:C	:C	:C	0	0	:C	0	0	0
a3	p/st	3720244	:C	0	0	96	:C	0	:C	0	:C	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a4	p/st		0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a5	p/st		0	0	0	7925	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	:C	0	0	0
a6	p/st	90094	0	:C	0	0	0	0	:C	:C	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a7	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a8	p/st		0	0	0	0	:C	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	:C	0	0	0
a9	p/st		0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a10	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a11	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a12	p/st		0	0	0	0	0	0	:C	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a13	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a14	p/st		0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a15	p/st		0	0	0	:E	15048	0	:C	0	:C	:C	832	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3352	0	0	:C
a16	p/st		0	0	0	0	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a17	p/st	4525	0	0	0	0	:C	0	:C	0	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a18	p/st		0	0	0	0	0	0	:C	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a19	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a20	p/st		0	0	0	0	0	0	0	0	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a21	p/st		0	0	0	0	0	0	:C	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a22	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0
a23	p/st	2291	0	0	0	0	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	:C	0	0	0
a24	p/st	463561	0	:C	0	0	236521	0	0	0	:C	:C	:C	0	0	0	0	0	0	:C	0	0	0	0	0	:C	:C	:E	8633	0	0	0
a25	p/st	96269	0	0	:C	0	:C	:C	:C	0	:C	:C	795	0	0	0	0	:C	0	:C	0	0	0	:C	0	0	0	0	:C	0	0	0
a26	p/st	25302	:C	:C	:C	0	:C	0	0	0	:C	:C	:C	0	0	0	0	0	0	:C	0	:C	:C	:C	0	:C	:C	0	:C	:C	0	0
a27	p/st		:C	:C	:C	0	5208	0	0	0	0	:C	204	0	0	0	0	0	0	:C	0	:C	0	:C	0	0	0	0	140	:C	0	:C
a28	p/st	79918	:C	0	:C	0	2570	0	0	0	:C	:C	444	0	0	0	0	:C	0	:E	0	226	0	0	0	:C	0	5	:C	:C	0	0
a29	p/st	52847	:C	:C	0	0	4740	0	0	0	0	:C	71	0	0	0	0	:C	0	:C	:C	:C	0	0	:C	0	0	0	1751	0	0	0

Statistics on the production of manufactured goods Sold Volume ANNUAL 2006, by country

	Unit	EU 27	BE	BG	CZ	DK	DE	EE	IE	GR	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	RU	SI	SK	FI	SE	UK	HR	IS	NO
a1	kg		:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	:E	0	0	0	0	0	0	23	0	0	0	0	0
a2	kg	757731	0	0	:C	0	:C	0	0	0	:C	:C	360810	0	0	0	0	0	0	0	0	:C	0	:C	:C	:C	0	0	:C	0	0	0
a3	p/st	3521312	:C	0	0	306	:C	0	:C	0	:C	:C	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	:C	0	0	0
a4	p/st		0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a5	p/st		0	0	0	:E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a6	p/st	26798	0	:C	0	0	0	0	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a7	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a8	p/st		0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	:C	0	0	0
a9	p/st		0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a10	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a11	p/st	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a12	p/st		0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a13	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a14	p/st		0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a15	p/st		0	0	0	:E	17138	0	:C	0	:C	:C	866	0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	2745	0	0	:C
a16	p/st		0	0	0	:E	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a17	p/st	64	0	0	0	0	:C	0	:C	0	:C	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	:C	0	0	0
a18	p/st	1	0	:C	0	0	0	0	:C	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a19	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0
a20	p/st		0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a21	p/st		0	0	0	0	0	0	:C	0	0	:C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
a22	p/st		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0
a23	p/st		0	:C	0	58	:C	0	0	0	:C	0	0	0	0	0	0	0	0	0	0	:C	0	0	0	0	0	0	0	0	0	0
a24	p/st	552194	0	:C	0	0	242909	0	0	0	0	:C	:C	0	0	0	0	0	0	:C	0	:C	0	0	0	:C	:C	:C	3353	:C	0	0
a25	p/st	255148	0	0	0	0	:C	:C	:C	0	:C	0	773	0	0	0	0	:C	0	:C	0	:C	0	:C	0	0	0	0	:C	0	0	0
a26	p/st	24918	:C	:C	:C	0	:C	0	0	0	:C	0	:C	0	0	0	0	0	0	:C	0	:C	0	:C	0	:C	:C	0	:C	0	0	0
a27	p/st		:C	:C	:C	0	5607	0	0	0	0	0	204	0	0	0	0	0	0	:C	0	:C	0	:C	0	0	0	0	195	:C	0	:C
a28	p/st	23752	:C	0	:C	0	5202	0	:C	0	:C	0	474	0	0	0	0	:C	0	:E	0	361	0	0	0	:C	0	:E	:C	0	0	0
a29	p/st	57434	:C	:C	0	0	4548	0	0	0	:C	:C	69	0	0	0	0	:C	0	:C	0	:C	0	0	0	0	0	0	1969	0	0	0

Annex 6
Import and export of mercury waste reported to the Basel-secretariat

All EU Member States are Parties to the Basel Convention and report annually to the Basel Secretariat on generation, import and export of hazardous waste by waste category and disposal operation.

Mercury waste is for the reporting specifically included in the waste category Y29 "Wastes having as constituents: Mercury; mercury compounds".

Some mercury may also be included in some more mixed categories like:

Y1 Clinical wastes from medical care in hospitals, medical centers and clinics

Y14 Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known

Y18 Residues arising from industrial waste disposal operations

R and D codes for waste disposal operations applied in the tables below:

R1	Use as a fuel (other than in direct incineration) or other means to generate energy
R2	Solvent reclamation/regeneration
R4	Recycling/reclamation of metals and metal compounds
R6	Regeneration of acids or bases
R5	Recycling/reclamation of other inorganic materials
R6	Regeneration of acids or bases
R12	Exchange of wastes for submission to any of the operations numbered R1-R11
R11	Uses of residual materials obtained from any of the operations numbered R1-R10
R13	Accumulation of material intended for any operation in Section B
D1	Deposit into or onto land, (e.g., landfill, etc.)
D5	Specially engineered landfill, (e.g., placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D9	Physico chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A, (e.g., evaporation, drying, calcination, neutralization, precipitation, etc.)
D10	Incineration on land
D12	Permanent storage (e.g., emplacement of containers in a mine, etc.)

Reported import of Y29 "Wastes having as constituents: Mercury; mercury compounds" in 2004

Country of import	Amount imported (in metric tons)	Country of origin	D code	R code
AT	0.2	DE		R4
	2.2	FI		R4
	42.0	SI		R5
BE	94.0	DK		R4
	158.0	FR		R4
	84.0	GB		R4
	28.0	IE		R4
	47.0	LU		R4
	732.0	NL		R4
	307.0	NL		R5
CH	14.1	GB		R4
	3.3	NL		R4
DE	19.0	AT	D12	
	6.8	AT		R4
	267.6	AT		R5
	100.8	BE	D12	
	141.2	BE		R5
	22.0	BG		R5
	298.0	CH	D12	
	1330.8	CH		R4
	588.6	CH		R5
	0.4	CS	D1	
	9.0	CY		R5
	14.7	DK		R4
	302.6	DK		R5
	13.5	ES		R4
	6.6	ES		R6
	5.1	FI		R4
	113.4	FR	D12	
	0.5	FR		R4
	107.6	FR		R5
	12.0	GB		R5
	20.0	IT		R5
	0.9	LT		R13
	14.3	LU		R13
	24.4	NL	D12	
	5.9	NL		R1
	201.7	NL		R3
	383.0	NL		R4

Country of import	Amount imported (in metric tons)	Country of origin	D code	R code
	1768.7	NL		R5
	4.1	PH		R5
	37.0	PL		R5
	0.9	PT		R13
	514.4	SE		R4
	38.5	TH		R4
	4.0	TR	D9	
DK	2.0	NO		R
	28.0	SE		R4
ES	10.0	PT	D5	
FR	20.7	BE		R4
	85.5	CH		R4,R11
	68.0	LU		R4,R5
GB	4.0	DE		R4
	40.0	IE		R4
LV	36.1	LT		R4
NL	6.5	BE		R4
	8.3	BE		R4
	2.3	FR		R4
	6.0	IE	D10	
	99.6	TH		R4
NO	304.0	SE		R11
SE	2.0	DK		R4
	2.0	NO		R4
Total import	8614.9			

Reported export of Y29 "Wastes having as constituents: Mercury; mercury compounds" in 2004

Country of Export	Waste streams	Amount exported (in metric tons)	Country of destination	D code	R code
AT	phosphores	21.0	DE	D12	
	amalgam waste	0.4	DE		R4
	fluorscent tubes	37.0	DE		R4
	fluorescent tubes	96.0	DE		R4
	chemicals	49.0	DE		R4
	round cells	8.0	DE		R4
	fluorescent tubes	96.0	DE		R5
BE		266.0	DE		R5
		204.0	DE	D12	
		7.0	DE		R4
		7.0	DE		R12
		20.0	FR		R4
		14.0	NL		R4
BG	Used Fluorescent lamps Solid	60.0	DE		R4,R5
CH		5.0	AT		R4
		661.0	DE		R4
		270.0	DE	D12	
		14.0	FR		R4
DE		9.9	AT		R4
DK		21.0	DE	D12	
		35.0	DE		R5
		246.0	DE		R4
ES		7.0	DE		R6
		14.0	DE		R4
FI	Waste amalgame	1.6	AT		R4
	Waste amalgame	0.6	DE		R4
	Waste containing mercury	4.5	DE		R4
FR		60.0	BE		R4
		60.0	BE		R5
		25.3	BE		R4,R5
		133.1	BF		R4
		49.0	DE		R5
		253.7	DE	D12	

Country of Export	Waste streams	Amount exported (in metric tons)	Country of destination	D code	R code
		19.0	NL		R4
GB	Fluorescent Light Tubes And Lamps	83.7	BE		R4
	Fluorescent Light Tubes And Lamps	12.2	DE		R5
GR		3.8	DE	D10	
HR		183.6	DE		R4
IT	hazardous wastes	62.0	DE		R4,R5
LT		36,000.0	LV		R4
		46,183.0	UA		R4
		36,000.0	UA		R4
LU		29.0	BE		R4
		16.0	DE		R13
		101.0	FR		R4
		18.0	BE		R4
NL		104.8	BE		R3
		30.3	BE		R4
		788.3	BE		R5
		3.3	CH		R4
		3.0	CH	D15	
		422.8	DE		R4
		24.4	DE	D12	
		2,049.6	DE		R5
NO		5.0	DK		R13
		7.0	SE		R4
SE	batteries	476.0	CH		R4
	amalgam waste	7.0	DE		R4
	mercury waste	603.0	DE		R4
	fluorescent tubes	28.0	DK		R4,R5
	fluorescent tubes	332.0	NO		R4
SI	Mercury and mercury compounds	15.0	AT		R5,R4
Total reported export		126,366.9			
Total reported export (excl. LT)		**8,183.9**			

Note: Similar large quantities exported from Litauen were also reported for 2003. As the reported export to Latvia is 1000 times the reported import to Latvia it is estimated that the large quantities are due to a punctuation error.

Source: http://www.basel.int/natreporting/2004/compII/index.html

Import/export between Member States for the same waste category in 2003 is shown the following tables. The tables were compiled by the European Topic Centre for Waste, Copenhagen.

Country of import	Country of origin (according to data from import countries), 2003																									
	AD	AT	BE	BR	CH	DE	DK	ES	FI	FR	GB	IE	IS	IT	JP	LT	LU	NL	NO	PL	PT	SE	SF	SI	TR	US	YU
AT					1	27				12												5	4			0	
BE-Flemish Region					6		146			204	111	17					49	912									
DE		121	157	12	404		345	6	16	21	88	7		6	2		14	4669	21	48	10	43		20	1		0
DK													0					5				101					
ES	4																										
FR			7					13																			
LV																36				170							
NL			41							4												10					
SE							2																				
UK						5						51															

Country of export	Country of import (according to data from export countries), 2003													
	AT	BE	CH	DE	DE, LT, USA	DK	ES	FR	GB	LT	LV	NL	NO	SE	UA
AT				127											
BE-FL				181								15			
CZ	0														
DE	10								5						
DK		146		317								4		2	
EE															29
ES				7											
FI	1			16											
FR	9	487		202								933			
HU				791											
IE		20		17					12			33			
LT											36,000				46,300
LU		54		16				86							
LV										0					
NL		648	3	2087											
PL					290										
PT		1		10			65								
SE				11		101						10	138		
SI				20											
UK		118		88											

Annex 7

Questionnaire to Member States

Questionnaire prepared by COWI for the European Commission, DG Environment.
Please address any questions regarding the questionnaire to Federica Andreoli, COWI at fean@cowi.com

Please return the filled in questionnaire to fean@cowi.com before 11 January 2008

Any reports or other additional information available in hard copy only, can be mailed to COWI A/S, Havneparken 1, DK-7100, Denmark, Attn. Jakob Maag.

Contact information	
Country	
Name and address of Institution	
Web page	
Contact person	
Telephone number of contact person	
E-mail address of contact person	
Date	

For the following questions requesting quantitative data on mercury, we are interested in the current situation in your country as well as the historical (and expected future) trends. So if you have data, projections or qualitative considerations about the past and/or future trends, these will be of great value for the study.

Filling in the tables

In order to be able to compile and compare the data across countries we have prepared a number of tables for a consistent reporting of the information. Please add rows to the tables as necessary. In case you have only partial information (e.g. a total for the country) please fill in what is available and leave other cells open.

Some relevant information may not fit into the tables, and in this case we would appreciate if you add this information under "additional information" or enclose the original documents. You do not need to care about the lay-out of information pasted into the questionnaire, as it will be processed later.

Most tables include the option of giving the answer that data are not available, or that the process does not take place in your country. In such cases, please put a mark in the relevant box in order to distinguish your answer from "no answer" during the final compilation of the data.

If your answer is based on a published document, please add a reference to the document. When additional information concerns information in a specific table row, please add the row number.

DG Environment's stakeholder consultation

Some of the questions posed here were also asked during DG Environment's stakeholder consultation process conducted in 2005 before the development of the Commission's proposal for export ban and storage of mercury. If your country has previously answered a specific question, kindly indicate it in each table. Country submissions for that previous process will be reviewed and taken into consideration for this assessment.[1]. New or updated data on the same issues will of course be highly appreciated.

Supplementary material

If you have reports, memorandums, product brochures or other material describing the subjects raised in the questions below, this may be of great value for the study. Please submit such material with your reply to this questionnaire, or supply *specific* links to where this material can be found on public Internet sites. If the mate-

[1] If needed, you can check your country's earlier response at DG Environment's mercury home page at http://ec.europa.eu/environment/chemicals/mercury/consultation_responses_implem.htm

rial is in other languages than English, German, French or Scandinavian languages, we would very much appreciate a short summary in English of the subjects covered in the reports/material.

Appendixes

In Appendix 1, we have included a list of reports, papers etc., which we know already, and which you therefore do not need to send or find links for; you can simply refer to them in your response, as applicable.

A list of known types of mercury applications and products is given in Appendix 2 for reference.

1 Current consumption of mercury

Kindly report, for major product and process applications, the mercury consumption in your country by year and application, preferably for 2-3 years if such data are available, as trade and consumption may fluctuate significantly from year to year, and we intend to describe the average situation. If you have data on trends that may not fit into the tables, please add this information below the tables.

In the following we distinguish between 1) mercury used for production of mercury containing products and in production processes (e.g. chlor-alkali), and 2) mercury in products sold in your country, some of which may have been imported. The latter corresponds to what is often designated "consumption of mercury by product group". A list of known types of mercury applications and products is given in Appendix 2 for reference.

Mercury use in industrial processes and for <u>production</u> of mercury containing products					
No data available __ Mercury not used in processes or for production __ Data already submitted for the stakeholder consultation __					
	Process / produced product	Mercury consumption, t/year			Comment
		2004	2005	2006	
1	Chlor-alkali production (including paper mills)				
2	Polyurethane production				
3	Small scale gold and silver mining				
4					
	Production of:				
5	Dental amalgams				
6	Light sources				
7	Medical thermometers				
8	Other thermometers				
9	Switches, contacts and relays (electrical)				
10	Other measuring and control equipment (non-electrical)				
11					
12	Batteries				
13	Laboratory chemicals				
14	Other uses of metallic Hg				
15					
16	Mercury compounds (esp. Hg chloride, Hg oxide, and phenylmercuric acetate)				
17					
18					
19					
20					

Additional information:

	Mercury amounts in products <u>sold</u> in the country (mercury consumption by product group)				
	No data available __ Data already submitted for the stakeholder consultation __				
	Product type (add product types as necessary)	Total mercury amounts in products sold in the country, t/year			Comment
		2004	2005	2006	
1	Dental amalgams				
2	Light sources				
3	Medical thermometers				
4	Other thermometers				
5	Switches, contacts and relays (electrical)				
6	Other measuring and control equipment (non-electrical)				
7					
8					
9					
10	Other uses as metal				
11	Batteries				
12	Laboratory chemicals				
13					
14					
15	Mercury compounds (esp. Hg chloride, Hg oxide, and phenylmercuric acetate)				
16	Total				

Additional information:

2 In your country are there any producers of mercury containing products?

For identified producers of mercury containing products in your country, kindly report:

	Producers of mercury containing products			
	No data available __ No use of mercury for production in the country __ Information already submitted for the stakeholder consultation __			
	Product type	Mercury use for the production, t/year	Year	Name and address of producers, contact details
1				
2				
3				
4				

Additional information:

3 Does your country export any mercury containing products?

Kindly report, for major product and process applications, the mercury quantities in products exported from your country by year and application.

Mercury amounts in products exported from the country							
No data available __ Data already submitted for the stakeholder consultation __							
	Product type (add product types as necessary)	Export to countries within the EU			Export to countries out- side the EU		
		Mercury amounts in exported products t/year	Year	The products are mainly produced within the country (yes/no)	Mercury amounts in exported products t/year	Year	The products are mainly produced within the country (yes/no)
1	Dental amalgams						
2	Light sources						
3	Medical thermometers						
4	Other thermometers						
5	Switches, contacts and relays (electrical)						
6	Other measuring and control equipment (non-electrical)						
7							
8							
9							
10	Other uses as metal						
11	Batteries						
12	Laboratory chemicals						
13							
14							
15	Mercury compounds (esp. Hg chloride, Hg oxide, and phenylmercuric acetate)						

Additional information:

4 Substitution status and production of mercury-free alternatives

a) Appendix 2 to this questionnaire contains a list of intentional mercury uses and existing alternatives. For mercury uses for which your agency/organization has information about the use of alternatives, kindly fill in your understanding of the current state of substitution in your country, following the instructions given in the appendix.

b) For identified producers of mercury-free alternatives in your country, please fill in the table.

Producers of mercury-free alternatives			
No data available __ Data already submitted for the stakeholder consultation __			
	Product type	Mercury use it substitutes for	Company name, city of main office and other contact details
1			
2			
3			
4			

Additional information:

5 Mercury waste management and waste flows in your country

We seek information that can illuminate the pathways and flows of mercury in various waste streams in the EU. Please fill in the following tables concerning disposal, export and/or recovery of mercury containing waste in your country.

Disposal of mercury containing waste within the country										
No data available __ Data already submitted for the stakeholder consultation __										
	Waste code (EWL)	Waste type	Landfilled		Incinerated		Recovered		Other (specify below)	
			Waste, t/year	Mercury, t/year	Waste, t/year	Mercury, t/year	Waste, t/year	Mercury, t/year	Waste, t/year	Mercury, t/year
1	06 03 13 06 04 04	Hg selenium waste from zinc production								
2	19 01 05 19 01 10	Activated carbon or filtercake waste from flue gas cleaning								
3	18 01 10	Dental amalgam waste								
4	05 07 01	Hg waste from natural gas cleaning								
5	16 06 03	Used silver oxide batteries								
6		Used alkaline and zinc-manganese batteries								
7		Hg lamp waste								
8		Meas./control equipment (thermometers, barometers, manometers, etc.)								
9		Waste metallic mercury								
10		Pesticides/fungicides containing Hg								
11										
12										
13		Total								

Additional information:

Export of mercury containing waste for recovery							
No data available __ Data already submitted for the stakeholder consultation __							
	Waste code (EWL)	Waste type	Export for recovery		Year	Recovery process	Country receiving the waste
			Waste, t/year	Mercury contents, t/year			
1	06 03 13 06 04 04	Hg selenium waste from zinc production					
2	19 01 05 19 01 10	Activated carbon or filtercake waste from flue gas cleaning					
3	18 01 10	Dental amalgam waste					
4	05 07 01	Hg waste from natural gas cleaning					
5	16 06 03	Used silver oxide batteries					
6	20 01 33	Unsorted household batteries					
7		Used alkaline and zinc-manganese batteries					
8		Hg lamp waste					
9		Meas./control equipment (thermometers, barometers, manometers, etc.)					
10		Waste metallic mercury					
11		Pesticides/fungicides containing Hg					
12							
13							
14		Total					

Additional information:

6 Does your country have facilities for recycling/recovery of mercury from wastes such as consumer products like batteries, lamps and thermometers?

Supply of mercury from post-user recycling					
No data available __ No facilities in the country __ Data on facilities already submitted for the stakeholder consultation __					
	Name of facility, town	Types of waste supplied	Treatment method	Mercury amount recovered, tonnes	Year
1					
2					
3					

Additional information:

7 Is mercury produced as a by-product of extraction or refining of metals, cleaning of natural gas, or other processes in your country?

Note: If already included in one of the “waste” or “recovery” tables above, please explain.

Supply of mercury from by-products of extraction of metals, cleaning of natural gas, etc						
No data available __ No by-product mercury supplied in the country __ Data already submitted for the stakeholder consultation __						
	Source of by-product mercury	If the mercury ends up in waste:		If the mercury is processed for marketing:		Year
		Amount of mercury in the waste, t/year	how is it managed ?	Amount of mercury produced, t/year	Form of mercury (pure/ which compounds)	
1						
2						
3						
4						

Additional information:

8 Does your country have legislation on mercury that goes beyond EU legislation ?

a) On restrictions for marketing, use or export of mercury containing products?

Restrictions for marketing, use or export of mercury containing products which go beyond EU legislation?			
No legislation beyond EU legislation __ Information already submitted for the stakeholder consultation __			
	Name of the legislation and year of its formal adoption.	A short summary describing the key features beyond EU legislation	Specific Internet links to the legislation/regulation
1			
2			
3			
4			

b) On mercury waste management?

Waste management legislation/regulation which go beyond EU requirements, and which significantly affect the mercury waste management situation in the country			
No legislation beyond EU legislation __ Information already submitted for the stakeholder consultation __			
	Name of the legislation and year of its formal adoption.	A short summary describing the key features beyond EU legislation	Specific Internet links to the legislation/regulation
1			
2			
3			
4			

c) On monitoring and/or transfers of elemental mercury?

Additional information:

9 Have any significant (>50kg) mercury metal stocks been identified in your country?

Identified mercury metal stocks					
No data available __ No stocks of mercury in the country __ Data already submitted for the stakeholder consultation __					
	Town, region	Stock type	Estimated amount of mercury in tonnes	State of the mercury (pure, compounds, waste, ect.)	Owners name
1					
2					
3					

In case certain data types cannot be disclosed, please report as much as possible, the mercury amounts being the most important. The stocks might be held at active or closed chlor-alkali facilities, stocks at non-ferrous metal smelters, or other industrial facilities, publicly owned stocks or identified private stocks (e.g. dental supply, non-ferrous metals traders), concentrated mercury-containing waste (other than wastes already identified above), or other readily transportable stocks which may similarly be a current or future source of supply of mercury.

Additional information:

10 Have any mercury contaminated sites been identified in your country?

Please list major identified sites/areas of severe mercury contamination in your country, if any. Please add a note with a few lines summary of the history and characteristics of the contaminated site, original source of the mercury contamination and plans or considerations of decontamination, if any, including technical methods, if considered. Please indicate for each specific site, if the details of identification can be reported explicitly, or if it must be reported as an anonymous site. In case certain data cannot be disclosed, please report as much as possible, the area/volume and approximate location being the most important.

Identified sites contaminated with mercury						
No data available __ No mercury contaminated sites in the country __ Data already submitted for the stakeholder consultation __						
	Location (town, region)	Area of the contami-nated site, m^2	Volume (m^3) and/or weight (tonnes)	Amount of mercury, tonnes	Original state of the mercury (pure, compounds, waste, ect.)	Owners name
1						
2						
3						

The contaminated sites might include former or operating chlor-alkali facilities, non-ferrous metal smelters, thermometer production or other industrial facilities where mercury has been used or stored, or other deposits or natural recipients of waste or materials or pollution with severe mercury contamination. Compared to the stocks already dealt with in question 8 above, these sites are characterised by mercury being mixed with soil, construction materials, or other materials, meaning that the mercury involved cannot be readily transported from the site in a concentrated form. Kindly coordinate response to this question with response to question 8 to avoid overlap.

Additional information:

11 Mercury accumulated in society, including in "hidden" stocks in society

We seek information about mercury circulating in or accumulated in society. This is for example the case in products which have a long life and are still in use, such as in medical thermometers and thermostats in the homes, in mercury switches in telephone hand sets, and many others. This is also the case in forgotten or hidden mercury metal, mercury compounds, or mercury containing products, such as for example mercury forgotten in school or university laboratories or in workshop shelves, or mercury caught in the water traps and piping in laboratories or dental clinics, etc.

Accumulated/circulating mercury in society can have many origins. Many of the mercury uses listed in Appendix 2 could be accumulated in society, notably those that can have a long technical life, or are incorporated into (and hidden in) long-life appliances, or can be thought of as technically valuable or merely fascinating by individuals who are not aware of the environmental risks mercury poses (and therefore be kept after active use, rather than handing them in for proper disposal).

To our knowledge this is a relatively poorly described subject, so any data, reports etc. that can describe aspects of such accumulation of mercury in society will be of great value for this study; this may be on an aggregated societal level, or for some specific mercury uses, or focused on some specific users. If the data are described in other languages than English, German, French and Scandinavian languages, kindly provide a short summary in English of the subjects covered in the reports/material.

Additional information:

12 Supplementary material

Please list all supplementary documents and indicate whether the document is enclosed or is available via the Internet. Please note that Appendix 1 includes a list of reports, papers etc., that we have already on file.

	Name of document	Enclosed	URL (Internet address of document)
1			
2			
3			
4			
5			

Short summaries in English of relevant key findings and issues dealt with (add row number):