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

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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.

*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

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.

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 were still used within the EU. As the mercury containing biocides are not included in the Review Programme under the Biocide Directive they should have been phased out by September 2006 and the mercury containing biocides are not further lawfully 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.

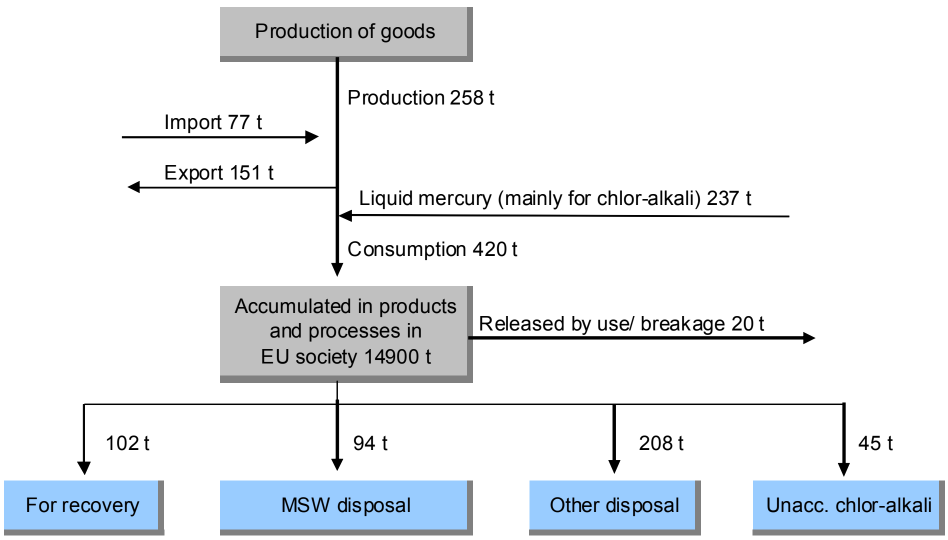
The numbers in Table 0-3 represent the midpoints of varying ranges of uncertainty. For example, the recycling rates for measuring equipment and miscellaneous uses represent more uncertainty than other categories due to the diversity of products and uses. Relatively low recycling rates were found for 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, no mercury containing biocides are included in the Review Programme

under the Biocide Directive and they should have been phased out by September 2006. 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.

*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.

*Table 0-4 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 | 10-100 (long term) | not yet quantified | Alternatives are not available for all applications |