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Preparation of a global legally binding instrument on mercury

Potential costs and benefits associated with each provision listed in paragraph 27 of Governing Council decision 25/5

Note by the secretariat

1. At its first meeting, which took place in Bangkok from 12 to 16 November 2007, the Ad Hoc Open-ended Working Group on Mercury discussed a number of strategic objectives and possible measures for achieving them, which are listed in annex I to the report of that meeting (UNEP(DTIE)/Hg/OEWG.1/6). Also at that meeting the Working Group requested the secretariat to undertake intersessional work on the costs and benefits associated with each strategic objective to inform the working group at its second meeting, which took place from 6 to 10 October 2008 in Nairobi. In response to that request the secretariat prepared the report set out in document UNEP(DTIE)/Hg/OEWG.2/5/Add.1, which was a draft report based on a study of mercury emissions being conducted by the United Nations Environment Programme.

2. At its meeting in Bangkok from 19 to 23 October 2009, the ad hoc open-ended working group to prepare for the intergovernmental negotiating committee on mercury agreed on a list of information that the secretariat would provide to the committee at its first session to facilitate its work. Among other things, the secretariat was requested to provide an update of the report set out in document UNEP(DTIE)/Hg/OEWG.2/5/Add.1.

3. The secretariat has accordingly prepared an updated version of the report. It comprises an executive summary and a detailed discussion of the potential costs and benefits associated with each provision listed in paragraph 27 of Governing Council decision 25/5. The full report, including both the executive summary and the detailed discussion, is presented in the annex to the present note in English only, while document UNEP(DTIE)/Hg/INC.1/19 contains the executive summary of the report in the official languages of the United Nations. As was the case with the original report, both the executive summary and the full report are being circulated without formal editing.

* UNEP(DTIE)/Hg/INC.1/1.

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Annex

UNEP Report

on

Potential costs and benefits associated with each of the provisions listed in paragraph 27 of Governing Council decision 25/5

Contents

Executive summary

1. Mercury is an important environmental contaminant. This contaminant is toxic, persistent and long-lived in the atmosphere and can be transported globally. International action is required to reduce environmental and health risks on the local, regional and global scales.

2. This report presents a qualitative assessment of potential costs and benefits associated with each of the provisions identified for inclusion in a comprehensive and suitable approach to mercury by the Governing Council in paragraph 27 of its decision 25/5. It was originally prepared to present the potential costs and benefits associated with each of the strategic objectives identified by the ad hoc open-ended working group on mercury at its first meeting in from 23 to 16 November 2007. The report has been updated to reflect the publication of the new report on emissions presented to the Governing Council at its twenty-fifth session held in Nairobi from 16 to 20 February 2009. It has also been reorganized to present the available information in accordance with the issues within the comprehensive approach on mercury as set out out in paragraph 27 of decision 25 of the Governing Council. Within this structure, it can be seen that there is some information available for measures which may be developed under each of the areas identified in decision 25/5.

3. The costs include the economic costs of introducing the necessary equipment or technological solutions as well as possible other actions to obtain the mercury reduction. Costs are defined as being small, medium and large, based on the highest cost of abatement for a given strategy, whether that be a technological answer or another means to address the challenge.

4. Benefits of reducing mercury emissions include economic, ecological, human health and social benefits. For ingested mercury, the benefits are estimated to be $12,500 USD per kg of mercury.[1] For inhaled mercury, the benefits are between $1.34 and $1.22 per kg of mercury.

5. In conducting the cost-benefit analysis, the benefits are assessed on the basis of the impact of the reduction of mercury releases, and are then related to costs. Statements regarding the benefits of activities are based on the consideration that the benefits are large if they exceed the costs by at least a factor of 2. If the benefits are equal or lower than costs, then it is considered that the benefits are small. Medium benefits are between the large and small benefits.

6. While all provisions to be addressed in the negotiations have been assessed, assessment in detail was possible only where information was available. In particular, the costs and benefits of reducing emissions from coal burning have been addressed in some detail in this report.

7. In assessing ways to reduce anthropogenic mercury emissions, technological and non-technological measures have been considered. A number of technological measures are available for reducing mercury emissions from anthropogenic sources where mercury is a by-product (for example, power plants, smelters, cement kilns, other industrial plants), waste disposal and other uses. These measures differ with regard to emission control efficiency, costs, and environmental benefits obtained through their implementation. Very often mercury emissions are substantially reduced by equipment employed to reduce emissions of other pollutants. The best example is the reduction of mercury emissions achieved through the application of desulfurization measures.

8. The analysis also took account of the range of efficient, non-technological measures and pre-treatment methods which are also available for the reduction of mercury releases from various uses of products containing mercury. These measures include bans on use of products containing mercury, and cleaning of raw materials before their use (for example coal cleaning). These measures also include energy conservation options, such as energy taxes, consumer information, energy management and improvement of efficiency of energy production through a co-generation of electricity and heat in coal-fired power plants.

9. The costs of reducing mercury emissions discussed in this report are linked to the economic costs of introducing the necessary equipment or undertaking other necessary actions to obtain the reduction. These costs include the investment costs and operational and maintenance costs.

10. A summary of the costs and benefits for a number of activities, organized by the provisions set out in the Governing Council decision are presented in Table 1 below.

1 A conversion figure of 1 USD = 0.64 € has been used throughout this report.

Table 1: Costs and benefits of Mercury emission reduction for various reduction options

Issues within the comprehensive and suitable approach to mercury	Reduction option	Costs	Benefits
(b) To reduce the supply of mercury and enhance the capacity for its environmentally sound storage	Reduction of supply from mining and extraction	Small → Medium	Large
	Reduction of supply from decommissioned cells and stockpiles	Small → Medium	Large
(c) To reduce the demand for mercury in products and processes	Reduction of Mercury consumption in VCM and chlor-alkali production	Small → Large	Medium → Large
	Reduction of Mercury use in products	Small	Large
	Reduction from dental practice	Small → Large	Medium
(d)To reduce international trade in mercury	Reduction of Mercury trade emissions	Small	Large
(e) To reduce atmospheric emissions of mercury	Reduction from coal usage	Medium →Large	Large
	Artisanal and small – scale gold mining	Small → Large	Small → Large
	Reduction from industrial processes	Medium → Large	Medium → Large
(f) To address mercury containing waste and remediation of contaminated sites	Reduction of waste generation	Small → Large	Large
	Promotion of Mercury waste collection and treatment	Small → Medium	Large
	Reduction from waste disposal	Medium → Large	Large
	Prevention of contamination from spreading	Large	Medium → Large
	Control and remediation of contaminated sites	Small → Medium	Large
(g) To increase knowledge through awareness raising and scientific information exchange	Increase of knowledge among states	Small → Large	Large
	Increase of knowledge among users and consumers	Small	Large

11. It can be seen from this table that costs and benefits vary significantly between sectors.

12. The final conclusion of the reported work is that there are benefits to be derived from investment in reducing mercury emissions and exposure in the future primarily for the sake of improvement of human health and more generally improvement of human welfare, including such effects as a lessening of potential negative effects on intelligence and ability. Measures involving the application of technology, such as implementation of installations to remove mercury from the flue gases in electric power plants, waste incinerators, and smelters are rather expensive (medium to large costs) compared to non-technological measures, such as prevention activity, capacity building, and promotion of mercury-containing waste separation (small to medium costs). Both groups of measures could result in large benefits. Parallel application of these, depending on resources, would be appropriate.

Introduction

13. Mercury is an important environmental contaminant requiring action from policy makers, industry, and the general public. This contaminant is toxic, persistent, and transported long distances in the atmosphere and food chain. Burning fossil fuel (primarily coal) is the largest single source of emissions from human sources, accounting for about 45% of total anthropogenic emissions (UNEP 2008).

14. During the last decade major progress has been made in the assessment of emissions of mercury from various anthropogenic sources in various parts of the world. This progress has been reviewed by Pacyna et al. (2006) and has been used to assess the past, current and future emissions of mercury. It is estimated that the total anthropogenic emission of mercury in the year 2005 was about 1930 tonnes, distributed along various categories.

15. The largest emissions of mercury to the global atmosphere occur from combustion of fossil fuels, mainly coal in utility, industrial, and residential boilers. As much as 46.5 % of the total emission of mercury emitted from all anthropogenic sources worldwide in 2005 came from combustion of fossil fuels. Emissions of mercury from coal combustion are between one and two orders of magnitude higher than emissions from oil combustion, depending on the country. Emissions during the artisanal small scale gold production contributed about 18 %, followed by non-ferrous metal manufacturing, including gold (about 10 %), and cement production (about 9 %) (UNEP 2008).

16. Emission projections for mercury in 2020 were also estimated within this project (UNEP, 2008) and another project GLOCBA-SE prepared for the Nordic Council of Ministers (Pacyna et al.,2008). Three scenarios were developed: Status quo scenario, Extended Emission Control scenario and Maximum Feasible Technological Reduction scenario. The **status quo scenario** assumes that current patterns, practises and uses that result in mercury emissions to air will continue. Economic activity is assumed to increase, including in those sectors that produce mercury emissions, but emission control practices remain unchanged. The **extended emission control scenario** assumes economic progress at a rate dependent on the future development of industrial technologies and emission control technologies, i.e. mercury-reducing technology currently generally employed throughout Europe and North America would be implemented elsewhere. It further assumes that emissions control measures currently implemented or committed to in Europe to reduce mercury emission to air or water would be implemented around the world. These include measures adopted under the LRTAP Convention, EU Directives, and also agreements to meet IPCC Kyoto targets on reduction of greenhouse gases causing climate change (which will cause reductions in mercury emissions). The **maximum feasible technological reduction scenario** assumes implementation of all solutions/ measures leading to the maximum degree of reduction of mercury emissions and its loads discharged to any environment; cost is taken into account but only as a secondary consideration.

17. It can be concluded from the scenario estimates that a significant increase of about one quarter of the 2005 mercury emissions is expected in 2020 if no major change in the efficiency of emission control is introduced (the status quo scenario). A decrease by one third of the total emissions of mercury in 2005 can be expected in 2020 if the assumptions of the extended emission control scenario are met. As reduction of up to a half of the 2005 total emission can be achieved by 2020 if the assumptions of the maximum feasible technological reduction scenario are met. These scenarios are used as the basis for discussion on the costs and benefits of taking action on mercury reduction.

18. Mercury is intentionally used globally in a variety of industrial applications, products and other applications. Global consumption patterns have recently been assessed in UNEP (2008) where also emissions of mercury from intentional uses were estimated. Intentional uses of mercury were summarised by different geographical regions and by major use category. For purposes of estimating product related emissions, mercury ‘consumption’ was defined in terms of regional consumption of mercury products rather than overall regional ‘demand’. For example, although most measuring and control devices are produced in China (reflected in Chinese ‘demand’ for mercury), many of them are exported, ‘consumed’ and disposed of in other countries.

19. The major mercury applications and intentional use sectors are:

a. **Artisanal and small-scale gold mining (ASGM)**. The largest global user of mercury, use reportedly continues to increase with the upward trend in the price of gold, and is inextricably linked with issues of poverty and human healthb. **Production of vinyl chloride monomer (VCM)**, especially in China, is another area of major concern, especially as it is not yet clear where much of the mercury – estimated to be several hundred tonnes – goes as the catalyst is depleted.

c. **Chlor-alkali production (CA).** The chlor-alkali industry is the third major mercury user worldwide. The mercury based technology is being phased out in many regions but continues to be used in others.

d. **Batteries** The use of mercury in batteries, while still considerable, continues to decline as many nations have implemented restricting policies. Large quantities of batteries with low mercury content are still produced as are button cell batteries, containing up to 2% mercury.

e. **Dental applications**. Some countries have implemented measures to greatly reduce the use of dental amalgams containing mercury and dental use of mercury is declining. However, the speed of decline varies widely, so that mercury use is still significant in most countries.

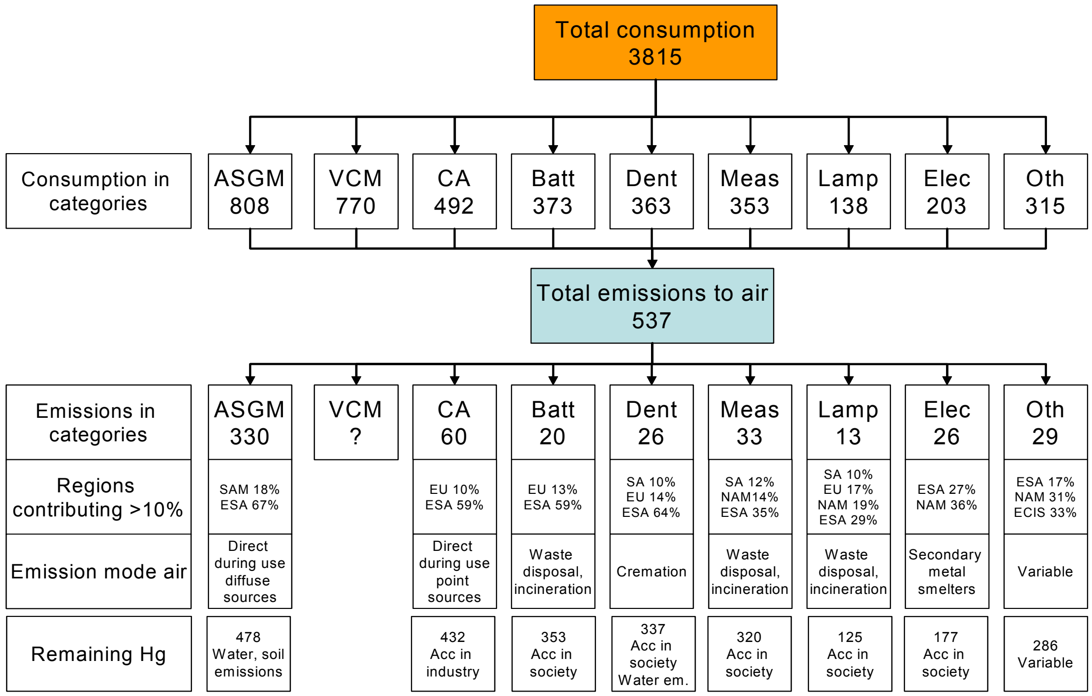
f. **Measuring and control devices**. There is a rather wide selection of mercury containing measuring and control devices, including thermometers, barometers, manometers, etc., still manufactured in various parts of the world, although most international suppliers now offer mercury-free alternatives.

g. **Lamps.** Mercury containing (fluorescent tubes, compact fluorescent, HID, etc.) lamps remain the standard for energy-efficient lamps, where ongoing industry efforts to reduce the amount of mercury in each lamp are countered, to some extent, by the ever-increasing number of energy-efficient lamps purchased and installed around the world.

h. **Electrical and electronic devices**. Due to the RoHS Directive in Europe, and similar initiatives in Japan, China and California, among others, mercury-free substitutes for mercury switches, relays, etc., are being actively encouraged, and mercury consumption has declined substantially in recent years. At the same time, the US-based Interstate Mercury Education and Reduction Clearinghouse (IMERC) database demonstrates that mercury use in these devices remains significant.

i. **Other applications of mercury**. This category has traditionally included the use of mercury and mercury compounds in such diverse applications as pesticides, fungicides, laboratory chemicals, in pharmaceuticals, as a preservative in paints, traditional medicine, cultural and ritual uses, cosmetics, etc. However, there are some further applications that have recently come to light in which the consumption of mercury is also especially significant such as the use of mercury catalysts in the production of polyurethane elastomers and the use of mercury in porosimetry.

20. In UNEP (2008) emissions of mercury from product categories have been calculated using distribution factors for the mercury consumed in the different products and emission factors to air for releases of mercury from the different paths of the mercury in the products. The general methodology is further described in Kindbom and Munthe (2007). In Figure 1, an overview of intentional mercury consumption and emissions is presented.



Abbreviations
Categories
ASGM: Artisanal and small scale gold mining
VCM: Vinyl chloride monomere production
CA: Chlor alkali production
Batt: Use and disposal of batteries
Dent: Dental amalgam (emissions only related to cremations)
Meas: Measurement and control devices
Lamp: Light sources
Elec: Electronic devices
Oth: Other uses e.g pesticides

Abbreviations
Regions
SAM: South America
SA: South Asia
EU: European Union
ESA: East and southeast Asia
NAM: North America
ECIS: Non EU European countries and CSI

Figure 1. Overview of intentional mercury use and emissions to air. Apart from the consumed and emitted amounts from different categories, information on the main regions where emissions occur, the main emission mode (i.e. source type) and an indication of the fate of the fraction of mercury consumed but not emitted to air ("Remaining Mercury"). All figures expressed in tonnes.

21. The overview presented in Fig. 1 provides a guide to the discussion of different management strategies discussed in the following chapters. The main point is that intentional mercury use can result in environmental emissions in various manners.

22. The costs of reducing mercury emissions is in this project linked to the economic costs of introducing the necessary equipment or introducing other necessary actions to obtain the reduction. In general, the term “cost” is often used when referring to both private cost and social cost, where the social cost is the sum of private- and external costs. When taking into account the social cost, this means that all costs in principle need to be internalised in the product price in order to give products their real price. Who is bearing this cost (the producer or the consumer) is determined by price- and market mechanisms often referred to as “elasticity” by economic theory. The effect of external factors such as pollution controls on production costs may either be absorbed by the producer, or passed on to the consumer, depending on this elasticity of the market.

23. The benefits of reducing the mercury emissions include a spectrum of social, economic, ecological, and human health benefits. For example, mercury exposures through fish consumption (as well as other pathways), can cause a range of human health effects in particular neurological effects, including reductions in IQ (Intelligence Quotient) among children. Dietary methyl-mercury is almost completely absorbed into the blood and distributed to all tissues including the brain; it also readily

passes through the placenta to the fetus and fetal brain. One of the measures of benefits is the prevention of IQ loss by reducing exposures. Other benefits to human health could include lower incidence of other types of neurological effects and lower incidence of some types of cardiovascular disease. Ecological benefits include less adverse effects to wildlife, while an economic benefit would be seen from fewer fish consumption advisories with a consequent boost for the recreational and commercial fishing industries. The benefits and costs of fish consumption advisories for mercury were discussed by Jakus et al. (2002).

24. Critical elements in estimating the cost of methyl-mercury exposure and risk from fish consumption would need to consider the species of fish consumed, the concentrations of methyl-mercury in the fish, the quantity of fish consumed, and how frequently fish is consumed. Those who regularly and frequently consume large amounts of fish -- either marine species that typically have much higher levels of methyl-mercury than the rest of seafood or freshwater fish that have been affected by mercury pollution -- are more highly exposed. Because the developing fetus may be the most sensitive to the effects from methyl-mercury, women of childbearing age are regarded as the population of greatest interest. In the United States, EPA believes that between 1 and 3 percent of women of childbearing age (i.e., between the ages of 15 and 44) eat sufficient amounts of fish to be at risk from methyl-mercury exposure, depending on the methyl-mercury concentrations in the fish. Advisories in the United States have been issued by 39 states and some Tribes.

25. The societal benefits due to the reduction of damage cost to the society from exposure to mercury pollution (societal cost) on global scale are now being studied within the GLOCBA-SE project (Pacyna et al., 2008). This project uses the results from the EU (European Union) DROPS project (DROPS D5.1 available from Pacyna, 2008). The overall objective of the DROPS project was to provide a full-chain analysis related to impact of health protection measures related to priority pollutants as identified by the EU Environment and Health Action Plan, in order to support the development of cost effective policy measures against pollution related diseases and their wider impacts. Mercury was one of the contaminants studied within the DROPS project. Neurotoxic impacts were found as the main human health end point for mercury. The damage cost data obtained in the DROPS project were estimated for inhalation of mercury polluted air and ingestion of mercury contaminated food, separately. The annual cost of $12,500 per kg of mercury was accepted for the ingestion pathway. In the case of inhalation, the amount of $1.34 /kg of mercury (the case for Poland) was used for the countries in Asia (except Japan), Eastern Europe, Africa and South America, while $2.21/kg of mercury was used for the rest of the world. These values were used in the GLOCBA-SE project to estimate the total damage cost to the society, defined as the societal cost. This cost is related to IQ loss, through loss of earning, loss of education, and opportunity cost while at school. The social benefits associated with IQ increase as a result of emission reductions were assessed taking into account the difference between the damage costs for the scenario with no improvement of mercury emission control (the status quo scenario) and the damage costs for the scenario with improvement of mercury emission control (the extended emission control Scenario. Based on a preliminary assessment, it was concluded that the annual social benefits can be as high as 11 billion US$ for this scenario.

26. The benefits of reduced mercury releases can be significantly higher for certain subpopulations that are more likely to be affected by fish contamination (e.g., the Native Americans and Asian Americans whose cultures include larger consumption rates of fish compared to the average American). Also, it is important to keep in mind that the cost per tonne reduction and benefit estimates are strongly correlated with baseline air emissions situations in countries, as well as with source and population information. The U.S. or the European Union estimates cannot be transferred and applied to tonnage reductions in another country given variable baseline mercury levels. The population near coastal regions may be higher, and the fish consumption rate may be higher than in the United States or in the European Union. These factors would lower the cost/tonne estimate and raise the benefits.

27. The reductions of mercury emissions can be obtained within various economic sectors, generating these emissions.

28. This report presents a qualitative assessment of potential costs and benefits associated with each of the provisions identified for inclusion in a comprehensive and suitable approach to mercury by the Governing Council in paragraph 27 of its decision 25/5. It was originally prepared to present the potential costs and benefits associated with each of the strategic objectives identified by the Ad hoc Open Ended Working Group on mercury by its first meeting in October 2007. The report has now been updated to reflect the publication of the new report on emissions presented to the Governing Council at its twenty-fifth session, and has also been reorganized to present the available information in relation to the provisions for the negotiations. Within this structure, it can be seen that there is some information available for measures which may be developed under each of the provisions identified in decision 25/5

29. This assessment is general in nature quantifying costs and benefits as small, medium, and large for the following specific sectors within the overall provisions:

a. reduce mercury supply from a hierarchy of sources,
b. reduce mercury consumption in VCM and chlor-alkali production,
c. reduce mercury use in products, incl. Packaging,
d. reduce mercury in dental practises,
e. reduce international trade of mercury and mercury containing products,
f. reduce mercury emissions from coal usage,
g. reduce mercury emissions from artisanal and small-scale gold mining,
h. reduce mercury emissions from industrial processes,
i. reduce generation of waste containing mercury,
j. reduce emissions to air from incinerators and reduce migration and emission of mercury from landfills
k. promote separate collection and treatment of mercury-containing wastes, and
l. increase knowledge of and capacity to manage mercury.

30. The purpose of this report is to provide qualitative assessment of costs and benefits. The costs defined as small, medium and large are related to the highest cost of abatement for a given strategy (emission category).

31. The benefits are then related to costs. It was assumed in this project that the benefits are large if they exceed the costs by at least a factor of 2. If the benefits are equal or lower than costs, then it was assumed that the benefits are small. Medium benefits are between the large and small benefits.

32. A recent review of socio-economic consequences of mercury use and pollution is presented in Appendix 1. This review has been published by Swain et al in Ambio, Vol. 36, No. 1 in February 2007 with a co-authorship of Jozef M. Pacyna (Swain et al., 2007). A summary of economic analyses that have been performed on the costs or benefits of reducing mercury emissions or just reducing exposure through fish consumption advisories is presented. This document can be regarded as a major introduction to the reported work.

1 To reduce the supply of mercury and enhance the capacity for its environmentally sound storage - Reduction of supply from mining and extraction of virgin mercury and other ores (relates to trade and hierarchy)

1.1 Overall assessment of costs and benefits

33. *Qualitative Cost Assessment: small, medium*

34. The reduction of primary mercury mining is estimated as a relatively inexpensive way of reducing mercury emissions, but the cost distribution is likely to affect the less developed countries the most.

35. *Qualitative Benefit Assessment: large*

36. Since the reduction in mercury supply is characterised as an up-stream abatement option, the qualitative benefit assessment is estimated as large, although there will be feedback mechanisms reducing the initial effect.

1.2 Mercury mining as a source of mercury emissions

37. The current main mercury mines are in Khaydarkan in Kyrgyzstan (550 tonnes) and China (ca. 200 - 650 tonnes and growing). Previously, the Almadén mine in Spain supplied some 240 tonnes and Algeria supplied an equal amount. The Almadén mine is closed since 2004, and the state owned corporation is currently involved mainly in trading of mercury. The mine in Algeria is closed since 2003 when unfavourable conditions made mercury mining too expensive at the site (MBM 2005). While the Almadén mine was still in use, some 10 – 30 tonnes of mercury was directly emitted from the mining of mercury. Primary mercury mining is still a large source of potential mercury emissions and adverse environmental effects.

1.3 Mercury abatement efficiency and costs

38. The costs for abatement of mercury emissions via reduction in mercury mining will vary according to local conditions. As an example, the mercury mine in Algeria was put out of use in 2003 due to unprofitability, not environmental reasons (MBM 2005). But mercury is an important metal for some purposes, and easy access to this metal might be considered important for economic growth in some regions, for example China. From the production side, foregone profits if terminating a mercury mine, might be offset by other investment opportunities, but the major part of the costs will be born by mercury buyers who are short of substitutes for mercury.

1.4 Benefits of mercury emission abatement by reduction in mercury mining

39. The reduction in mercury mining has a number of environmental benefits. The obvious reduction in mercury related effects will be combined by the environmental effects related to reduced mining activities and the following turnover of soil. However, one should be aware that the benefits related to mercury emissions will be offset to some extent by the feedback mechanisms following the price increase induced by the reduction in mercury mining. The extent of these feedback mechanisms is currently unknown. Examples of feedback mechanisms are; increased mining activities in other mines; re-opening of previously closed mines; increased recycling activities etc. It should be noted that increased efforts to recycle mercury will decrease the mercury being discarded as waste.

2 To reduce the supply of mercury and enhance the capacity for its environmentally sound storage - Reduction of mercury supply and management of mercury from decommissioned chlor-alkali cells and existing stockpiles

2.1 Overall assessment of costs and benefits

40. *Qualitative Cost Assessment: Variable, depending on whether a storage infrastructure needs to be developed.*

41. *Qualitative Benefit Assessment: Large for chlor-alkali, large for products and processes.*

42. Large stocks of mercury exist on the global level. These include government stocks, surplus mercury in chlor alkali industries and stocks at mercury mining facilities (Maxson 2006).

43. The generation of mercury from recycling and the recovery of mercury from decommissioned chlor-alkali plants have become increasingly significant contributors (10-20% in recent years) to global supplies because recycling has increased and the production of mined mercury has declined. However, in the interest of eliminating surplus mercury supplies from the global market, the European Union (EU) and the United States have enacted regulations for mercury export bans. These bans will prohibit the export of mercury from 2011 in the EU and 2013 in the United States. The supporting analysis suggests that recycled and by-product mercury (along with reduced mercury mine production, as necessary) will be more than adequate to meet global mercury demand (Maxson, 2006). It is estimated that the switch to mercury-free technology in the chlor-alkali industry will release around 12,000 tonnes of metallic mercury (EC, 2006a).

44. The US government, through the Defense National Stockpile Center (DNSC), owns one of the world's larger stocks of Mercury, and in the early 1990s began selling it on the international market after declaring it unneeded for future defense needs. A moratorium on sales was declared in 1994 as a result of concerns that marketing Mercury may contribute to global environmental contamination. The relative merit of selling versus retiring the Mercury was studied (DNSC, 2004), and in February 2006 the US government announced that the stockpile of some 4400 t of Mercury would be stored indefinitely in a warehouse.

45. Global demand of mercury has decreased from around 7 000 tonnes per year in the late eighties to 3 000 - 4000 tonnes in 2005 (Maxson, 2006). The supply to meet this demand is described in Table 19 and indicates that mining and by-product mercury is the main source of mercury to the global trade.

Table 19: Sources of Mercury supply (2005)

Sources of Mercury supply	Range of Mercury supply (Mt)
Mining and by-product Recycled Mercury from chlor-alkali wastes	1800-2200 90-140
Recycled Mercury-other Mercury from (decommissioned) chlor-alkali cells	450-520 600-800
Stocks	0-200
Total	3000 - 3800

Source: http://www.chem.unep.ch/mercury/PM-MercurySupplyTradeDemand-Final-Nov2006-PMformat19Jan07.pdf

46. Another example of decreasing demand is the USA where production exceeded the demand of less than 500 tonnes per year in the late nineties as presented in Figure 5 .

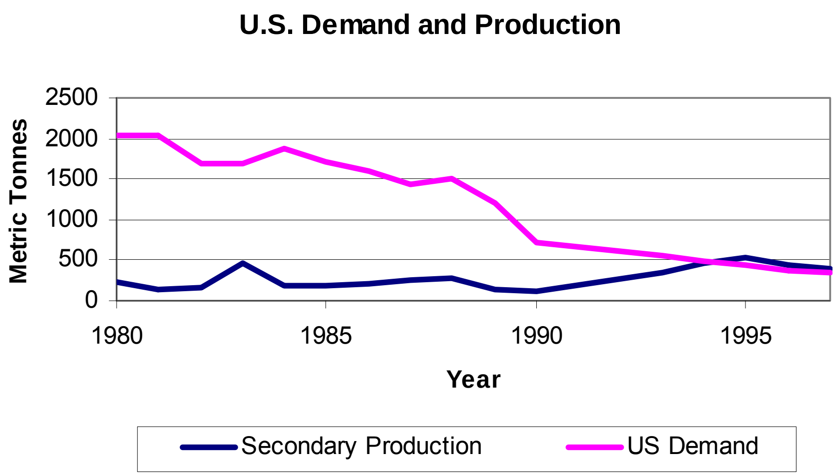


Figure 5: U.S. demand and Production

Source:(http://www.newmoa.org/prevention/mercury/breakingcycle/compendium/Weiler.ppt#256,1,Can the U.S. act alone on mercury?)

47. The reasons for the decreasing demand have been several including regulations and international agreements. The continued rate of decline in mercury demand will depend primarily upon reductions of use in the product manufacturing sectors (battery, electrical product, and measuring device) as well as in the industrial sectors chlor-alkali and vinyl chloride production. To reduce the consumption in the main consumption sector, small-scale gold mining, represents a major challenge.

48. A continued reduction of mercury demand driven by either environmental concern or economic realities will require the development of technological and economical instrument for the safe storage and management of surplus mercury.

49. For all excess mercury stocks, the cost of reducing the supply would be the opportunity cost to the forgone sale plus the cost of long term management of the excess stocks. The projected cost of storing federal mercury stockpiles (US$42 million over the next 40 years) in the United States could be used to project the costs associated with storing U.S. private stockpiles, but the numbers would vary based on the costs in an individual country. One issue to be mindful of in terms of supplies from decommissioned sources and stocks is the timing of making these supplies available on the market: there could be economic, social and environmental costs in introducing large supplies of mercury into the market at one time.

50. The main risks associated with stocks of mercury are associated with the fate of the mercury if sold and distributed on the global market. The risks as well as the potential management options will depend on the ultimate use of mercury and ultimately the amounts of mercury released to the environment in that application. However, to avoid any risks and to prevent potential future contamination, several countries in the developed world are promoting efficient management of existing stockpiles and mercury containing waste to prevent environmental contamination.

51. In Sweden for instance, the strategy is that mercury should not be recycled but should be finally disposed of in a safe and environmentally sound way. Using this as a starting-point, the Government has commissioned two enquiries into how such final disposal can be effected. In 2001, the Committee on the terminal storage of mercury proposed that a legal requirement for waste containing mercury to be stored permanently deep in bedrock. Waste owners should cooperate and bear the responsibility for the construction, location, building and management of a deep storage facility. An estimated total of 1 100 – 1 400 tonnes of waste containing mercury is waiting to be put into terminal deep storage

(http://www.regeringen.se/). The Swedish EPA has estimated the costs of deep storage of a facility of 1000-2000 tonnes mercury should be in the range of 200-300 million SEK (around 20-30 millions US$) (2001 prices). Hence on average the cost for 1500 tonnes would be 250 millions SEK (around 25 millions US$; 2001 prices). The cost per tonne would be around 170 000 SEK/tonne (or 17000 US$) (http://www.regeringen.se/content/1/c4/26/09/a4b611c4.pdf).

52. In order to manage, or retire excess mercury several potential alternatives have been identified. Through a contract with the U.S. Environmental Protection Agency's Office of Research and Development, SAIC (Science Applications International Corporation) has been developed a methodology to be used to evaluate, prioritize, and select alternatives in a systematic manner (Vierow 2002). This methodology identifies criteria for such an evaluation, such as environmental performance, catastrophic risks, need for regulatory changes, implementation considerations, and cost. A system to ascribe weightings, or the importance of one criterion over another, is proposed (with the assistance of a commercial software package). Finally, a total of 11 alternatives for the storage and treatment/ disposal of elemental mercury are evaluated according to these criteria. Preliminary results are presented in Table 20 to show how the alternatives compare to one another when evaluated using the methodology (Randall 2002): Assuming that only benefits (non-costs) or only costs are important. The second column ("overall") shows that the landfill options are preferred independent of the treatment technology. The storage options rank next, followed by the treatment technologies combined with mono-fills, bunkers, or mined cavities. The reasons why the landfill options are preferred become apparent when costs are considered. The third column of results shows the rankings if only cost is taken into account. The landfill options are cheapest and this clearly outweighs the relatively unfavorable rankings that result from a focus on the benefits. However, if the costs are not an important factor, then the three storage options occupy the first three places in the "non-costs only" ranking. The last column of shows unfavorable rankings for the operating costs of the storage options. This arises for two reasons: a) if storage continues for a long period, even relatively small per annum costs will add up; and b) storage is not a means for permanent retirement of bulk elemental mercury and the analysts assumed that, sooner or later, a treatment and disposal technology will be adopted, which adds to the cost. This is enough to drive the storage options out of first place in the base-case rankings. However, the analysis would support continued storage for a short period (up to a few decades) followed by a permanent retirement option. This would allow time for the treatment technologies to mature.

Table 20: Summary of results for 11 evaluated alternatives

	Ranking (as fraction of 1 000)					
	Overall		Non-Costs Only		Costs Only	
Alternative	Score	Rank	Score	Rank	Score	Rank
Stabilization/amalgamation followed by disposal in a RCRA-permitted landfill	137	1	99	5	217	1
Selenide treatment followed by disposal in a RCRA- permitted landfill	123	2	66	9	217	1
Storage of elemental mercury in a standard RCRA-permitted storage building	110	3	152	2	126	5
Stabilization/amalgamation followed by disposal in a RCRA- permitted mono-fill	103	4	92	7	135	3
Storage of elemental mercury in a hardened RCRA-permitted storage structure	95	5	173	1	44	6

Alternative	Ranking (as fraction of 1 000)					
	Overall		Non-Costs Only		Costs Only	
	Score	Rank	Score	Rank	Score	Rank
Selenide treatment followed by disposal in a RCRA- permitted mono-fill	94	6	74	8	135	3
Storage in a mine	81	7	140	3	44	6
Stabilization/amalgamation followed by disposal in an earth-mounded concrete bunker	70	8	108	4	42	8
Stabilization/amalgamation followed by disposal in a mined cavity	63	9	97	6	42	8
Selenide treatment followed by disposal in an earth-mounded concrete bunker	62	0	a*	a	A	a
Selenide treatment followed by disposal in a mined cavity	61	11	A	a	A	a
Number of alternatives evaluated	11	—	9	—	9	—
Total	1 000	—	1 000	—	1 000	—
Average score (total divided by number of alternatives, either 9 or 11)	91	—	111	—	111	—

Note: Shading indicates the highest ranking alternative. *) These options were evaluated for the overall goal but were not evaluated at the lower levels of cost and non-cost items separately, due to the low score from the overall evaluation. RCRA = Resource Conservation and Recovery Act

53. Hence, the methodology gives some ideas on the possible alternatives as well as the cost effectiveness of each of the alternatives. Furthermore, the methodology is designed to be flexible in order to allow for differences in criteria importance, the addition of other alternatives, and the substitution of better information (both qualitative and quantitative) as it is developed in the future.

3 To reduce the demand for mercury in products and processes - Reduction of mercury consumption in vinyl chloride monomer (VCM) and chlor- alkali production

3.1 Overall assessment of costs and benefits

54. *Cost Assessment: Small if achieved through best practices, possibly high per plant or for countries that have many plants, but small globally. If achieved through conversion, high capital cost. Small long-term cost for chlor-alkali, higher for individual facilities.*

55. *Benefit Assessment: Medium to Large for VCM, Large for chlor-alkali.*

3.2 Mercury in VCM production

56. The use of mercury as a catalyst in the production of VCM is a major use of and source of mercury emissions in a few countries, primarily in China, largely because it is a coal-based process compatible with the predominant raw materials in those countries (Maxson, 2006). While alternative processes are available, significantly more information on this sector is necessary to better understand the current operating practices of existing facilities and the mercury catalyst management processes before cost estimates can be made. Given the number of facilities using this process, requiring or encouraging their conversion or upgrading and enforcing consumption or release limits could be costly in the specific countries in question. Industry-to-industry technical exchange on best management

practices for the mercury catalyst and the exploration of alternatives could be less expensive, but information on the cost and technical issues for conversion has not yet been fully analyzed. There is some evidence that points to potential economic incentives for upgrades that could offset some of the cost.

57. The Natural Resources Defence Council, in collaboration with China's Chemical Registration Center, estimates that in 2004 the VCM sector was the largest user of mercury in China, consuming 700 metric tonnes per year. Multimedia releases from this sector are not well characterized. Also, due to increased demand for polyvinyl chloride(PVC), one estimate suggests that mercury use in this sector is projected to reach 1,000 metric tonnes by the end of the decade. Addressing this sector is likely to reduce global mercury risks significantly if the projected demand estimates for PVC are correct.

3.3 Mercury in chlor-alkali production

58. There are three different processes for chlor-alkali production. Two processes: the mercury method and the diaphragm techniques date from the end of the 19th century, while the third process: membrane technique was developed on an industrial scale in the 1970s. Membrane cells release less hazardous substances and are more energy-efficient than the older techniques (KEMI, 2004).

59. For chlor-alkali, the global trend for conversion to non-mercury cell technology or reductions in mercury use and emissions has been established, with chlorine and caustic soda now being produced using more efficient, environmentally friendly, non-mercury processes. As of 2004, there were approximately 150 chlor-alkali plants worldwide that still use mercury cell technology (UNEP, 2007).

60. There were about 14 U.S. facilities in the mid-1990s using the mercury-cell process (so-called mercury cell chlor-alkali plants: MCCAPs); this year only 5 such facilities will still be in operation. The existing U.S. facilities are subject to a technology based emissions standard (the MACT regulation), which requires controls and emissions limits for process vents and relatively stringent work practice standards or a cell room monitoring program to minimize fugitive emissions from the cell rooms. Mercury use by the U.S. chlor-alkali sector was reduced by 94 percent from 1995 to 2005, from about 160 tonnes in 1995 to 10 tonnes in 2005. Emissions were reduced about 50 percent from 1990 to 2002 (from about 10 tonnes to 5 tonnes), and are expected to decrease to 2.5 tonnes by 2008. These numbers suggest that the benefit of reducing mercury consumption in chlor-alkali production can be quite high, with little opportunity cost given industry trends.

61. According to Euro Chlor information, there remained at the beginning of 2005 over 50 MCCAPs in Europe that continue to use the mercury process to produce chlorine (Concorde, 2006). Mercury consumption and releases have been greatly reduced from the 500-1,000 tonnes per year estimated in the 1970's. However, the average age of the EU plants is nearly 35 years, and further efforts to reduce mercury releases below present levels may challenge the technical limits of what is possible without converting to a mercury-free process. Unacceptably high mercury emissions before and into the 1980's pressed the member countries of OSPAR (the Oslo and Paris Convention for the protection of the North Sea and North-East Atlantic) to recommend in 1990 that the mercury cell chlor-alkali process should be phased-out by 2010. The European IPPC Bureau, in its 2001 best available techniques (BAT) reference document on chlor-alkali industry, confirmed that the mercury cell process does not reflect BAT, and the IPPC Directive calls for non-BAT processes to be phased out by mid-2007. The implementation of the 1990 OSPAR Decision and the IPPC Directive as well, are ultimately the responsibility of each of the countries concerned. However, the countries uneven response to the OSPAR and flexible interpretation of the 2007 IPPC deadline reflect the diverse and shifting political and economic priorities of different countries within the EU (Concorde, 2006).

62. The Swedish Chemicals Inspectorate (KEMI) concludes that the use of mercury in the Swedish chlor-alkali industry should be covered by a general national ban (KEMI, 2004). KEMI also considered that mercury for chlor-alkali production should be granted a time-limited exemption from the ban and be allowed to be marketed and used until 31 December, 2009. It is interesting to note that according to KEMI, a national ban on the use of mercury in the chlor-alkali industry after that date will produce no greater further impacts for the companies affected beyond those which follow from the IPPC Directive.

63. In other larger EU countries there is no general agreement that a phase-out of the mercury process is needed before 2020 (Concorde, 2006). The production costs of these old plants are low.

64. The chemical industry has self-imposed a target for 2007 of 1 g mercury/ tonne of chlorine capacity. A discussion is now being carried out that this limit can be lowered to 0.75 g mercury/ tonne of chlorine capacity by 2012. It should be added that the best performing EU MCCAPs report emissions

in the range from 0.2 to 0.5 g mercury/ tonne of chlorine capacity, and this lower range of emission is reflected in the BAT reference document on chlor-alkali production. The phase-out of mercury in the chlor-alkali industry is expected to be a fairly straight-line phase-out of remaining mercury cell capacity by 2020 (EC, 2006). The industry has, through a voluntary agreement, committed to phase out the use of mercury by 2020.

65. Mercury emissions from MCCAPs in regions other than North America and Europe seem to be higher. Srivastava (2008) report that the mercury consumption in Indian companies are at least 50 times higher than in the world best companies. This high consumption of mercury results in emission of about 47 g mercury/ tonne caustic soda produced, one of the highest emission factors ever noted for this industry. Srivastava (2008) calls for a serious effort by the Indian chlor-alkali industry in moving towards membrane cell technology.

3.4 Cost and benefits of mercury emission reductions

66. Recent studies on the costs and benefits of reducing mercury emissions from US coal combustion facilities were used to derive conservatively estimated annual EU health benefit of some $39-47 per 1 gram of MCCAP atmospheric mercury emissions eliminated (Concorde, 2006).

67. The analysis Concorde (2006) also assesses the costs and benefits (especially energy savings, reduced costs of mercury monitoring and waste disposal, etc) to industry of converting a typical MCCAP to the membrane process. There are various cases of actual conversions that have generated an attractive two- to three-year return on investment. However, it was pointed out that an EU industry investment on average in conversion of the MCCAP process to membrane process may not show an attractive bottom-line return until close to 10 years. The Concorde (2006) study concludes that combining the considerable “bottom-line” benefits of MCCAP conversion with even a conservative estimate of the public health benefits, it can be expected that the overall benefits, even when accumulated over only 5 years, are nearly twice the costs associated with the technology transition. Therefore, the conversion of MCCAPs should be regarded as a high priority when discussing the whole range of public health and other benefits associated with industrial development of chemical industry.

68. More information on combined benefits and costs of converting European MCCAPs to membrane process is presented in Table 13 below.

69. The existing MCCAPs use various control techniques to reduce mercury emissions, including: 1) gas stream cooling, 2) mist eliminators, 3) scrubbers, and 4) adsorption on activated carbon or molecular sieves (e.g. US EPA, 1995). Gas stream cooling is often used as the primary mercury control technique or as a preliminary removal step to be followed by a more efficient control device. Mist eliminators can be used to remove mercury droplets, water droplets, or particulate matter from the cooled gas streams. Scrubbers are used to absorb the mercury chemically from both the hydrogen stream and the end box ventilation streams. Sulfur- and iodine-impregnated carbon adsorption systems are commonly used to reduce the mercury levels in the hydrogen gas stream if high removal efficiencies are desired. This method requires pre-treatment of the gas stream by primary or secondary cooling followed by mist eliminators to remove about 90 % of mercury content of the gas stream.

Table 13: Combined benefits and costs of converting European MCCAPs to membrane

Combined benefits and costs (billion euro of 2004)	***Estimated annual benefits & costs***	***During 5 yrs.***		***During 10 yrs.***	
		Discount rate 5%	Discount rate 10%	Discount rate 5%	Discount rate 10%
Present value – total conversion costs, including: Investment cost, cleanup, etc.	2.6 one-time	**2.6**		**2.6**	**2.6**
Present value total benefits, including:		**4.9**		**8.4**	**6.9**
Industry benefits		1.7		2.8	2.3
Health benefits*		3.2		5.6	4.6
Environmental benefits		not included		not included	not included
	various 0 annual significant				
Ratio of total benefits/costs		**1.9**		**3.2**	**2.7**

Assumptions for conversion of European MCCAPs to the membrane process:

annual chlorine production capacity ≈ 6 million tonnes

-10-15% of capacity will close rather than convert

-annual atmospheric mercury emissions ≈ 4-5 g Mercury per tonne chlorine capacity ≈25-30 tonnes mercury total

-annual health benefits >25 euro per gram of mercury emissions eliminated

-annual environmental benefits may be similar to health benefits, but are not quantified here

Note:

* Health benefits are based only on estimates of neuro-developmental impacts – specifically loss of intelligence – of methyl-mercury exposure in the US due to fish consumption, although there is evidence of other health effects as well. The figure of 25 euro per gram of mercury emissions eliminated (multiplied by 25-30 tonnes of mercury emissions eliminated upon full conversion) is a conservative estimate based on two key sources: one assuming human methyl-mercury exposure from consumption of both marine and freshwater fish, and the other assuming exposure from consumption of freshwater fish only.

76. Major review of information on the costs of abatement for existing MCCAPs was carried out within the EU ESPREME (http://espreme.ier.uni-stuttgart.de) and DROPS (http://drops.nilu.no) projects. The results for chlorine production are summarized in Table 14 below.

Table 14: Annual investment and operating costs for chlor-alkali industry.

Sector	**Emission control measures**	**Mercury reduction (%)**	**Annual costs (US$ 2008/ tonne chlorine)**		
			Annual investment costs	**Annual operating costs**	**Annual total costs**
Chlorine production (mercury cell plants)	good practices during maintenance and repair – optimized	20	0,02	0,02	0,04
	improvements of the mercury cells – state-of-the-art	15	0,06	0,02	0,08
	wet scrubber (WSC) with chlorinated brine or hypochloride addings- state-of-the-art	60	1,65	1,35	3,00
	virgin activated carbon injection (SIC)+FF - optimized	98		4,28	
	technology switching to diaphragm or membrane cells - BAT	100	36,96	0,00	36,96

4. To reduce the demand for mercury in products and processes - Reduction of mercury use in products, including packaging

4.1 Overall assessment of costs and benefits

77. *Qualitative Cost Assessment: Variable, ranging from small to large*

78. In the European literature on the reduction of mercury used studied for this report, the costs related to a reduction of mercury in household measuring products are estimated as small since there are many available substitutes at similar prices. For other products, the availability of substitutes is smaller. For many other regions, the economic and technical situation is less favourable for reduction of mercury use in products. The qualitative cost assessment therefore ranges from small to large.

79. *Qualitative Benefit Assessment: small*

80. For the European region, for which there available estimates, the total amount of mercury in household measuring products that are feasible to substitute are relatively small. For other products and regions, the potential is lower. Therefore, the qualitative benefit assessment remains small.

4.2 Mercury in products (incl. packaging) as a source of mercury emissions

81. Mercury-containing products are relatively scarce in Europe (except for products for dental practices) Therefore, measures aimed at reducing the amount of mercury will have relatively small effects on the use of mercury in society. The environmental impact of reducing the amount of mercury in products and mercury must be treated as relatively large since a removal of mercury in products is an

'up-stream' measure that indirectly affects 'down-stream' emissions such as emissions from incineration of waste, emissions from landfills and leakage to water and soil. Globally, the potential for reducing mercury in products will differ from the European situation. The differences relates to the level of economic and technical development, which in turn affects the local or regional availability of substitutes to mercury (Table 15).

82. An inventory of the amount of mercury demanded by relevant sectors shows that for EU-25, the amount of mercury demanded for use in products equals 155 tonnes (batteries, measuring & control, lighting, electrical & electronic, other). The other uses of mercury are covered in other chapters of this report.

Table 15: EU-25 and global mercury demand by sector (2005)

Mercury demand	**Global demand [tonnes]**	**EU 25 market demand [tonnes]**
Small-scale	1000	5
Chlor-alkali	619	190
Batteries	**400**	**20**
Dental	270	90
Measuring & control	**150**	**35**
Lighting	**120**	**35**
Electrical & electronic	**140**	**35**
VCM	700	Unknown
Other, laboratory, pharmaceutical etc	**40**	**30**
Total	3439	440

Source: EC 2006a

83. Also of importance for the emissions of mercury from products is the amount of mercury being recycled from these product categories. An estimate on the recovery of mercury specified in product categories is shown in Table 16 below. However, these estimates are uncertain on an EU level, and even more uncertain on a global scale.

Table 16: EU-25 and global product/process mercury recycling – 2005

EU25 and global product and process mercury recycling - 2005	**Mercury in EU-25 waste stream (t)**	**EU-25 Mercury recycled or recovered (%)**	**EU-25 Mercury recycled or recovered (t)**	**Mercury in global waste stream (t)**	**Global Mercury recycled or recovered (%)**	**Global Mercury recycled or recovered(t)**
SS gold mining	Not applicable	not applicable	Not applicable	Not applicable	not applicable	not applicable
Chlor-alkali	Not applicable	not applicable	32	Not applicable	not applicable	84
Batteries	**40**	**25%**	**10**	**500**	**15%**	**75**
Dental	72	25%	18	200	15%	30
Measuring & control	**42**	**25%**	**11**	**160**	**15%**	**24**
Lighting	**46**	**25%**	**11**	**150**	**15%**	**23**
Electrical & electronic	**42**	**25%**	**11**	**150**	**15%**	**23**
VCM	Unknown	unknown	unknown	700	43%	301
Other, laboratory, pharmaceutical, etc.	**36**	**25%**	**9**	**50**	**15%**	**8**
Total for these categories	278		101	1910		566

Source: EC DG-ENV (2006)

84. What can be seem is that the recycling rate is somewhere around 25 % in the EU and lower globally. For the products covered in this chapter it is estimated that some 254 tonnes of mercury in the EU-25, and 857 tonnes globally reach the waste stream without being recycled. This cause high potential for emissions from products once they reach the waste stream, which is covered in other chapters of this report.

4.3 Mercury abatement efficiency and costs

85. The European ban of household measuring devices containing mercury, due to be applied by member states from 3 April 2009 will mainly cause costs related to restructuring of firms. In Europe, there are substitutes available at similar prices for all household applications, so the ban would be easy to implement. The availability of substitutes is only one of the factors determining the costs of reducing mercury in products. However, other costs relating to administrative efforts such as legislation and efforts related to phasing out of mercury are very difficult to estimate and also very dependent on the availability of substitutes for mercury in products. The ban relates only to households since it is estimated that mercury in measuring devices for professional use is not possible to substitute given the technologies currently available and the extensive control of these professional devices (EC 2006b). If a ban only covers a certain region, and only production (not use) there is a risk of re-allocation of markets and production, which would decrease the impact of the abatement measure.

86. The impact assessment for the proposed amendment to the European Council Directive 76/769/EEC (EC 2006b) covers the potential impact from a European product ban on household measuring devices such as thermometers. The general conclusion here is that the use of mercury in measuring and control equipment for households can be reduced from ~55 tonnes to ~28 tonnes per year in EU 15 corresponding to a 50 % reduction of mercury use in this product category. The costs of this ban would come mostly as restructuring costs since there are already substitutes available at similar prices. The costs would mostly affect manufacturers of mercury thermometers, but these costs would be offset by the increased benefits for the manufacturers of non-mercury thermometers.

87. To reduce the use of mercury in batteries is already an ongoing process globally (EC DG-ENV 2006), and costs for continued reduction of mercury use in batteries should therefore be small.

88. The situation seems to be more difficult for electrical and electronic devices. Efforts are being made to promote mercury-free substitutes, but mercury use remains significant (EC DG-ENV 2006). This indicates that the reduction of mercury use in this product category would be associated with medium or high costs.

89. For lighting products, the availability of substitutes is smaller than for electrical and electronic devices (EC DG-ENV 2006). This indicates that the reduction of mercury use in lighting equipment is associated with high costs.

90. When studying the literature it is clear that the feasibility of any ban or restriction on products and packaging containing mercury will depend on what substitutes for mercury are available. Mercury has specific characteristics and it does not seem to be easily substituted in some products, for example some measuring equipments in hospitals.

91. The question of costs of reducing mercury in products and packaging is directly translatable to the question of whether there are compatible substitutes available at similar prices.

4.4 Benefits of mercury emission abatement

92. The benefit related to reduced mercury in household measuring products in the example above relates to relatively small amounts of mercury, ~28 tonnes. This reduces the total qualitative benefit assessment of such a measure. Also, the potential for re-allocation of markets and production further reduces the potential of such a measure. What increases the possible benefit however is that it would have effects both in the use part as well as in the waste part of the products' life cycle. In EC (2006b) it is estimated that the consumption of 33 tonnes of mercury for measuring devices would implicate some 8 tonnes of mercury emitted to air via landfills and incineration. A quick estimate would then indicate that reduced use of mercury in household measuring devices in EU-15 could reduce emissions by 6 tonnes annually. In extrapolating this estimate, the global reduction in emissions would be some 16 tonnes if the 150 tonnes of mercury used globally in measuring devices was reduced to 76 tonnes.

93. Given that the recycling rate for batteries, electrical & electronic devices as well as lighting equipment is estimated as equal to the recycling rate for measuring devices it is estimated that the emissions to air should be equal as well. However, due to the relative lack of substitutes, the potential emission reduction should be small for these product categories. Globally, it is indicated that the situation is less positive given that the recycling rate is lower and that the technical and economic availability of substitutes is low in many parts of the world. The benefit is therefore estimated as small.

5. To reduce the demand for mercury in products and processes - Reduction of mercury use in dental practice

5.1 Overall assessment of costs and benefits

94. Qualitative Cost Assessment: low to large for amalgam separator installation for the developed world. These costs would be much higher in the developing countries.

95. Qualitative Benefit Assessment: If the benefits are mainly related to the ingestion of fish these would in most cases not be greater than the costs.

5.2 Mercury abatement costs and benefits

96. Dental amalgam is a mixture of mercury with an alloy consisting of silver, tin, copper, and zinc particles. This has been used in dentistry to restore carious lesions in teeth for about 150 years, although there are records of its use as a dental filling material in China as early as the 7th Century (Phillips, 1991). Although dental amalgam is a source of exposure to elemental mercury and may be the source of health hazard, it is still the most commonly used material, comprising approximately 60% of all restorations (http://english.pravda.ru/news/science/06-06-2008/105448-dental-0).

97. As of 2008, the use of dental amalgam has been restricted in Sweden, Norway and Finland mainly for environmental reasons.

98. The question of direct impacts of the use of dental amalgam is controversial. Examples of studies showing negative impacts of dental amalgam have been presented e.g. Wojcik et al (2006). On the other hand, the American Dental Association Council on Scientific Affairs has concluded that both amalgam and composite materials are considered safe and effective for tooth restoration. The National Institutes of Health (NIH) has stated that amalgam fillings pose no personal health risk, and that replacement by non-amalgam fillings is not indicated. The US Food and Drug Administration is considering new labelling requirements for dental amalgams, and is also reviewing evidence about safe use, particularly in sensitive subpopulations. (http://www.fda.gov/cdrh/consumer/amalgams.html)

99. Hence, in the developed world there is no consensus to whether dental amalgam is a source of direct health hazard or not. Given the effects of mercury exposure through the environment, restrictions on the use and safe handling in dentistry to prevent releases of mercury to air and waste water have been imposed in several countries.

100. The amount of mercury used in dentistry in Europe in year 2000 was 70 metric tonnes, in the US was 51 tonnes, while worldwide (include Europe and US) was 272 metric tonnes,. The worldwide demand for mercury in dentistry is predicted to be 250 metric tonnes by the year 2020 as more people worldwide get access to dentistry (Jacobsson-Hunt, 2007).

101. Table 17 shows that only 15% i.e. 30 tonnes of dental mercury are recycled or recovered while 200 tonnes mercury are accumulated in waste streams at the global level in year 2005 (http://ec.europa.eu/environment/chemicals/mercury/pdf/hg_flows_safe_storage.pdf).

Table 17: Recycling of product/process mercury in the EU and globally in 2005.

EU-25 and global product/process mercury recycling – 2005

EU25 and global product and process mercury recycling - 2005	Hg in EU-25 waste stream (t)	EU-25 Hg recycled or recovered (%)	EU-25 Hg recycled or recovered (t)	Hg in global waste stream (t)	Global Hg recycled or recovered (%)	Global Hg recycled or recovered (t)
SS gold mining	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable
Chlor-alkali	not applicable	not applicable	32	not applicable	not applicable	84
Batteries	40	25%	10	500	15%	75
Dental	72	25%	18	200	15%	30
Measuring & control	42	25%	11	160	15%	24
Lighting	46	25%	11	150	15%	23
Electrical & electronic	42	25%	11	150	15%	23
VCM	unknown	unknown	unknown	700	43%	301
Other, laboratory, pharmaceutical, etc.	36	25%	9	50	15%	8
Total for these categories	278		101	1910		566

Note: If the Chinese industry estimate of VCM mercury catalyst recycling turns out to be optimistic (for example, if it is closer to 100 tonnes than 300 tonnes/yr), that single correction could make a very large difference in the global total for recycled mercury.

Sources: Author calculations based on responses to the Stakeholder questions posed by DG ENV to the different Member States in September 2005. See Czech Republic (2005), France (2005), Germany (2005), Netherlands (2005), Slovakia (2005), UK (2005). Also Brooks (2005), Maxson (2004, 2005), Euro Chlor reports to OSPAR.

102. As shown in Table 18 the abatement costs related to replace dental amalgam fillings with mercury free fillings at dentists and to dispose of the mercury safely are in the range of $129000 / kg Mercury where the reduction potential is large.

Table 18: Costs for strategies avoiding mercury pollution and their potential to reduce mercury pollution

Activity	Costs $/kg Mercury	Reduction potential	Place and year
Increase recycling of chair-side traps in dentistry	240	Medium	Minnesota 1999
Install amalgam separator	33000 - 1300000	Medium/ large	Minnesota 1999
Replace dental amalgam at dentists	129000	Large	Sweden 2004
Remove dental amalgam fillings at death	400	Large	Sweden 2004

Adapted from Hylander et al (2006).

103. As shown in Table 18 increasing recycling of chair-side traps in dentistry is a low cost strategies but the potential of reduction is medium. When it comes to installing amalgam separator where the potentials for reduction vary between medium and large depending on the kind of separator installed, the costs of the strategies range between $33, 000/kg mercury and $1300 000 /kg mercury. Furthermore, results of cost effectiveness analysis conducted by US EPA gave rise to the following results (http://www.epa.gov/ARD-R5/mercury/meetings/Vandeven.pdf):

a. purchase and installation of separators at an estimated 110 000 to 133 000 clinics will require $111 million to $266 million, industry-wide;

b. The operation and maintenance of these amalgam separators will require $78 million to $133 million per year;

c. Conservatively assuming a separator has a useful life of 10 years, the combined annual cost is $ 89 million to $160 million per year;

d. The annual cost of reducing one tonne of potentially bio-available mercury is $91 million to $282 million per tonne. That is $90625 /kg mercury and $281250/kg mercury , respectively.

104. Comparing the US EPA results to those presented in the Table 18, the first ones are in the lower range.

105. Since the benefits or the damage costs are mainly related to ingestion being $12,500/ kg mercury, most of the abatement costs presented here for capturing mercury used in dentistry are higher than the benefits. The use of non-mercury alternatives to dental amalgam for new fillings have a higher costs to consumers (2004 dental fees in the US indicated a $30 extra fee for composite fillings, based mainly on the increased time required). The incremental cost of composite fillings would be decreased if pollution effects were adequately factored in (http://www.mercurypolicy.org/new/documents/FINALReportfromMPPTestimony070708.pdf)

6. To reduce International Trade in mercury - Reduction of mercury emissions from international trade

6.1 Overall assessment of costs and benefits

106. The potential effect on costs and benefits are presented for three cases; trade ban from the European Union; seller-specified end-use restrictions; and disposal costs mandated via trade restrictions.

107. *Qualitative Cost Assessment: Variable, ranging from small to large.*

108. An export ban from the European Union is estimated as causing small costs since the total economic value of the ~800 tonnes mercury currently traded from EU corresponds to a relatively small economic value. Likewise, the cost estimate for end-use restrictions is small. These costs estimates do not include transactional costs, but an uncertain estimate of corresponding transactional costs indicates that these would constitute ~10% of the disposal costs.

109. *Qualitative Benefit Assessment: Variable, ranging from small to large*

110. An export ban from the European Union is estimated as having medium but variable benefits since reduced export from the European Union will result in reduced end use of mercury. The reduced use will be counteracted to some extent by increased production elsewhere. End-use restrictions are estimated as having medium benefits since they are focused on mercury uses with the worst environmental performance (ASGM).

111. Table 4 below presents a summary of available cost estimate for different final disposal solutions.

Table 4: Cost estimates for various disposal solutions. Information compiled from EC DG-ENV (2006a) and EC (2006)

Literature Source	Cost estimate	Estimate source
EC DG-ENV (2006)		
Deep bedrock respitory	~US$ 220 / Hg / year	(SEPA)
Permanent storage	~US$ 150 / tonne Hg / year	(SRIC)
Surface storage	~US$ 300 / tonne Hg / year	(US DNSC)
- Disposal in monofill	~US$ 7 000 - 19 000 / tonne Hg / year	(SAIC)
EC (2006a)		
- Costs of storage	~US$ 300 / tonne Hg / year	

112. It can be seen that the cost estimates linked to disposal in mono-fills represents an outlier in the cost estimates for final disposal, and these results should be considered with some caution.

6.2 International trade as a source of mercury emissions

113. EC DG-ENV (2006) gives estimates on the direct costs for final storage of mercury that will be a result of the export ban from the European Union. These estimates are given in the Table 5 below.

Table 5: Estimates of cost for final storage of mercury due to export ban from the EU

EU chlor-alkali industry		
Years	2005 – 2010	2011 - 2015
Amount of mercury available	494 t/y to be sold	582 t/y to be stored
Income/costs of storage per tonne	US$ 10 / kg sold	US$ 306 /tonne /year
Total yearly income / cost	US$ 4,9 million / year	~ - US$ 180 000 / year

source: EC DG-ENV 2006

114. For our purposes, the costs for the mercury producers of restricting trade are in principal made up out of two parts; foregone profits and costs of disposal. From a socioeconomic perspective however, the costs are only based upon the costs of disposal. The foregone profits are excluded from the socioeconomic costs estimates since they constitute restructuring costs. The economy will restructure from mercury trade into production and trade of a suitable substitute. The foregone profits will negatively affect chlor-alkali plants for example, but the foregone profits of the chlor-alkali industry induce increased profits in some other industry and are thereby offset. In this context, it should be mentioned that mercury trade is currently not a major source of income for any firm based in the EU (EC DG-ENV 2006).

115. It can be seen from Table 5 that the export ban will induce disposal costs corresponding to US$ 0.30 / kg per year for Europe. If putting these costs in comparison to the benefit estimates from the ESPREME study (Friedrich 2008), which presents external cost estimates of mercury to some US$ 12 500 / kg mercury emitted the net-benefit indicated is very large, ~ US$ 12 500 / kg. The benefit/cost ratio would equal 40 000, a very high number. However, the disposal costs are only related to the mercury stored and not to actual emissions to the environment so the comparison is not directly relevant.

116. In 2005, the global supply of mercury was 3690 tonnes (incl. 400 tonne from mercury stocks); the global demand was 3439 tonnes. For EU-25 the supply was 625 tonnes (incl. 0 tonne stock) and demand was 440 tonnes. For 2004, the import / export flows of 'elemental' mercury to and from EU-25 were 723 tonnes (US$ 3 615 000 - US$ 10 845 000) imported and 824 tonnes (US$ 4 120 000 - US$ 12 360 000) exported. The international market price for mercury has ranged between 5 and 15 US$ / kg mercury. The export flows from EU-25 were much smaller in 2004 (824 tonnes) than earlier (1658 tonnes in 2002, 1110 tonnes in 2003) due to new requirements on end-user specification from one of the main exporters of mercury. This requirement was installed to avoid exported mercury being used in ASGM in developing countries. The global trade patterns for 2004 are presented in Figure 2 below (EC DG-ENV 2006)

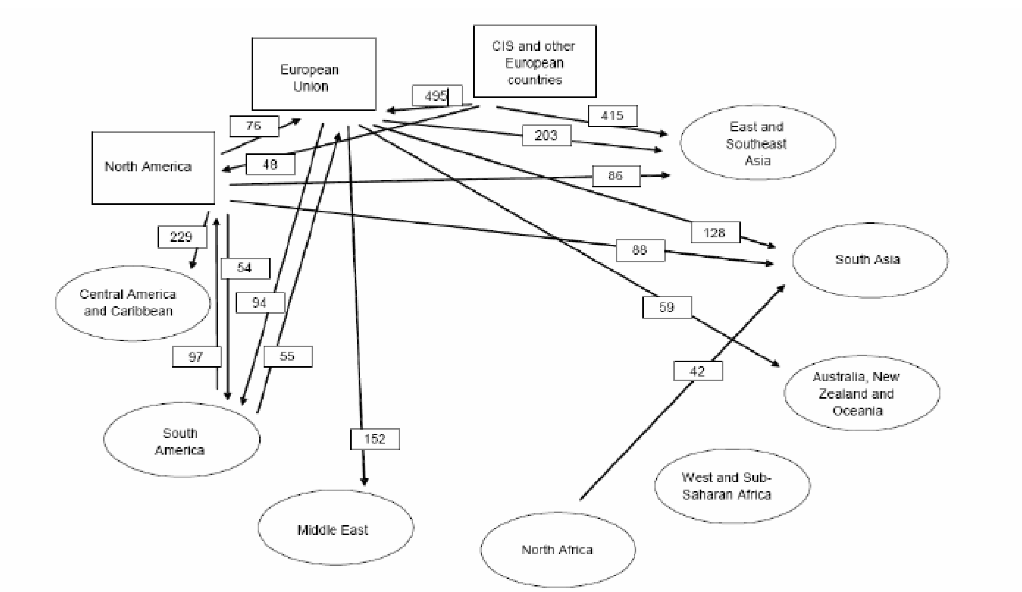


Figure 2: Global trade patterns for 2004 (EC DG-ENV 2006)

117. The countries, such as Spain, Netherlands, USA, United Kingdom, Germany, Belgium and Australia together exported more than 1325 tonnes of mercury to other than EU-25 in 2003 (EC DG-ENV 2006).

6.3 Mercury abatement efficiency and costs

118. When the EU introduces a mercury export ban (scheduled to be adopted in September 2008 and enter into effect 15 March 2011) there will be an income loss corresponding to $6.25 million / year for specific European firms and disposal costs corresponding to $ 0.16 million /year. The income losses will be offset by income increases in other firms. Other costs would include restructuring costs for firms. Globally there is a potential mercury price increase, but this can be counteracted by the availability of substitutes for mercury and increased domestic production of mercury. However, the net trade and global supply of mercury should be reduced. As an additional remark, EC (2006) estimates that a trade ban will have a neutral economic impact on the current traders of mercury in the EU.

119. User restriction is a voluntary way used within the EU to avoid traded mercury ending up in, for example,. small scale artisanal gold mining, which is usually the case with mercury exported from the EU (EC 2006). One of the major traders in the EU, MAYASA, decided in 2004 to restrict export to avoid exported mercury being used in ASGM in developing countries. The means used for enforcing this restriction is not specified (EC DG-ENV 2006). User restrictions involve a potential mercury price increase, but this can be counteracted by the availability of substitutes for mercury and increased domestic production of mercury. However, the net trade and global supply of mercury should be reduced due to the increased use of substitutes and increase in mercury prices.

120. Administrative costs related to a trade ban and disposal are very difficult to estimate, but estimates from EC (2006) indicate some 3 - 12 % of the disposal costs, or US$ 0.78 - 5 million for a ten year period.

121. This section has only addressed the impact of a ban on export by the EU, and only addressed direct costs involved in storage.

6.4 Benefits of mercury emission abatement

122. The benefit of an export ban is estimated as medium since the European Union currently supplies almost 1/4 of the global mercury traded globally, which indicates a large impact from an export ban. An export ban from the United States would be likely to have a similar benefit. The benefit is also considered as medium since an export ban will reduce final use, which has a larger effect than reducing emissions and leakage from final use. The benefits are considered as variable since it is difficult to divine which trade flows that will be reduced and the environmental impacts vary over regions.

123. The total amount of mercury not traded according to the example on end-use restrictions in EC DG-ENV (2006) reduced the amount of export from EU by 30 %. The benefit can be large since they occur in hot spots where the negative impacts are very large from using mercury.

124. The impact of the expansion of such export limitations globally has not been further investigated.

7. Reduce atmospheric emissions of mercury - Reduction of mercury emissions from coal usage

7.1 Overall assessment of costs and benefits

125. *Qualitative Cost Assessment: Variable, ranging from small (if used as an incremental approach with other pollution reduction measures) to large.*

126. *Qualitative Benefit Assessment: Large emission reduction of mercury, both globally and locally with consequent health benefits; Reductions of other air pollutants.*

7.2 Mercury emissions from coal combustion

127. Based on the latest inventories (particularly in UNEP, 2008), coal combustion is the largest emitting anthropogenic mercury source. The coal fired power sector is among the largest contributors to worldwide mercury emissions.

128. The mercury content in coal and the type and efficiency of emission control equipment are the most important parameters. The mercury content of coal varies from 0.01 to 1.0 ppm with an average of 0.1 ppm.

129. Various technologies within the same industry may generate different amounts of atmospheric emissions of mercury. It can be generalized for conventional thermal power plants that the plant design, particularly the burner configuration has an impact on the emission quantities. Wet bottom boilers produce the highest emissions among the coal-fired utility boilers, as they need to operate at the temperature above the ash -melting temperature (Pacyna, 1989).

130. Non-conventional methods of combustion, such as fluidized bed combustion (FBC) were found to generate comparable or slightly lower emissions of mercury and other trace elements than the conventional power plants (Carpenter, 1979; Abel et al., 1981). However, a long residence time of the bed material may result in increased fine particle production and thus more efficient condensation of gaseous mercury. Tests carried out in the former Federal Republic of Germany have shown that the residence time of the bed material can be regulated by changing the operating conditions of a given plant, the reduction of combustion temperature, coal size, moisture content, and bed flow rates

(Munzner and Schilling, 1985). A literature review of information on the influence of various FBC techniques on emissions of trace elements has been presented by Sloss and Smith (2000).

131. The load of the burner affects the emissions of trace elements including mercury in such a way that for low load and full load the emissions are the largest (Bakkum and Veldt, 1986). For a 50 % load the emission rates can be lower by a factor of two.

7.3 Mercury from combustion of fuels other than coal

132. Major revision of recent data on the mercury content in crude oil indicates the concentration range from 0.01 to 0.5 ppm. It is expected that mercury concentrations in residual oil are higher than those in distillate oils being produced at an earlier stage in an oil refinery. Natural gas may contain small amounts of mercury, but the element should be removed from the raw gas during the recovery of liquid constituents, as well as during the removal of hydrogen sulfide. Therefore, it is believed that mercury emissions during natural gas combustion are insignificant.

133. The influence of plant design or its size on atmospheric emissions of mercury from oil-fired boilers is not as clear as for the coal-fired boilers. Under similar conditions the emission rates for the two major types of oil-fired boilers: tangential and horizontal units are comparable (Pacyna, 1982).

7.4 Mercury abatement measures and their efficiency

7.4.1 Pre-treatment methods of Mercury emission control during coal combustion

134. Fuel washing and fuel substitution are the major pre-treatment measures to reduce emissions of various pollutants from coal combustion processes, including reduction of mercury.

Coal washing

135. Commercial coal cleaning (or beneficiation) facilities, particularly in the United States (e.g. NAPAP, 1990) are physical cleaning techniques to reduce the mineral matter and pyritic sulfur content. As a result, the product coal has a higher energy density and less variability (compared to feedstock coal) so that power plant efficiency and reliability are improved. A side benefit to these processes is that emissions of sulfur dioxide, as well as other pollutants including mercury can be reduced. The efficiency of this removal depends on the cleaning process used, type of coal, and the contaminant content of coal. Basic physical coal cleaning techniques have been commercial for over 50 years.

136. The cleaning of coal takes place in water, in a dense medium, or in a dry medium. Physical cleaning processes are based on either the specific gravity or surface property differences between the coal and its impurities. Jigs, concentrating tables, hydrocyclones, and froth flotation cells are common devices used in current physical coal-cleaning facilities.

137. The mercury concentrations in the raw coal, the clean coal, and the present reduction achieved by cleaning have been presented by Akers et al. (1993) for coals from various regions in the United States. The removal efficiency ranged from 0 to 60 % with 21 % as average reduction. Kraus et al. (2006) indicate that typically 10 to 50 % of the mercury in coal can be removed by in the cleaning process alone. This efficiency is highly dependent on the type of coal.

Fuel switching

138. The following options of fuel substitution are often considered in the electric utilities:

a. switching from high- to low-sulfur coal burnt in applicable coal-based generation (including switching directly from high-sulfur to low-sulfur supplies, blending high- and low-sulfur coal, cleaning high- and medium-sulfur coal, or a combination of cleaning and blending),
b. increasing the use of natural gas, or oil, and
c. increasing the use of alternate fuels or importing electricity to meet base load electric-generation requirements.

139. The two latter methods are the most interesting with respect to the reduction of mercury emissions. The substitution of coal by coal-bed methane to produce heat and electricity would result in decrease of emissions of various air pollutants, including mercury. The following action would be needed in the case of the substitution:

a. the modernization of existing utility and industrial heat producing plants,
b. the development of new methane burning boilers, and

c. the modernization of coal mines with respect to the better exploitation of coal-bed methane.

7.4.2 Primary measures to reduce mercury emissions during coal combustion

140. Primary measures of emission reduction include solutions where emission reduction occurs at emission generation point, e.g. application of various modifications of combustion process may reduce emissions from a given burner.

Non-conventional combustion technologies

141. Non-conventional methods of combustion, such as fluidized bed combustion (FBC) were found to generate comparable or slightly lower emissions of mercury and other trace elements compared to the conventional power plants (e.g. Carpenter, 1979, Abel et al., 1981). However, a long residence time of the bed material may result in increased fine particle production and thus more efficient condensation of gaseous mercury. Tests carried out in Germany have shown that the residence time of the bed material can be regulated by changing the operating conditions of a given plant, the reduction of combustion temperature, coal size, moisture content, and bed flow rates (Munzner and Schilling, 1985). A literature review of information on the influence of various FBC techniques on emissions of trace metals, including mercury has been presented by Sloss and Smith (2000).

Low NOx burners

142. Low NO_X technologies are also likely to reduce mercury emission in the exhaust gases due to the lower operating temperatures. Very limited information on this subject is rather inconclusive. While some sources indicate that the reduction can be achieved, preliminary results of staged combustion in atmospheric fluidized bed combustion (AFBC) units indicated that low NO_X had only little effect on trace element emissions (Smith, 1987).

7.4.3 Secondary measures to reduce mercury emissions from coal combustion

143. Secondary measures include technological solutions to decrease concentrations of mercury in the flue gas leaving the combustion zone.

144. Mercury enters the atmosphere from coal combustion in a gaseous form. However, de-dusting installations, such as electrostatic precipitators (ESPs) and fabric filters (FFs) can also remove up to 30 % of mercury from exhaust gases. One should note that ESPs are now commonly used abatement measures in major electric power plants and central heating plants worldwide.

145. The application of flue gas desulfurization (FGD) has a very important impact on removal of not only sulfur dioxide but also mercury. A number of studies have been carried out to assess the extent of this removal and parameters having major impact on this removal. These studies were reviewed in connection with the preparation of the EU Position Paper on Ambient Air Pollution by Mercury (EC, 2004). It was concluded that the relatively low temperatures found in wet scrubber systems allow many of the more volatile trace elements to condense from the vapour phase and thus to be removed from the flue gases. In general, removal efficiency of FGD installations for mercury ranges from 30 to 50%. It was also concluded that the overall removal of mercury in various spray dry systems varies from about 35 to 90%. The highest removal efficiencies are achieved from spray dry systems fitted with downstream fabric filters.

146. Higher mercury emission control efficiencies, exceeding 95 %, can be obtained through a combination of FGD and ESP's with "add on" type of equipment including sorbent injection. Sorbent injection generically describes the injection of powdered activated carbon (PAC) or other non-carbon sorbents into the flue gas for mercury control, while mercury oxidation enhancements are intended to improve the mercury capture efficiency of conventional control installations or downstream air pollution control devices by converting elemental mercury to a more reactive oxidized state (e.g. Jones et al., 2006)

147. Selenium scrubber is a wet media process for removal of fairly large quantities of mercury from the flue gas. The gaseous mercury reacts with activated amorphous selenium, which is circulating in a scrubber with a 20.0 to 40.0 % sulfuric acid. The mercury removal efficiency is between 90.0 and 95.0 %.

148. Carbon filter bed is another dry media process. Carbon filter bed technology is assumed by the U.S. EPA to remove 80 to 90 % of the mercury in the flue gas.

149. Lead sulfide process has also been recommended for removal of mercury. The flue gas containing mercury passes through a tower packed with lead sulfide coated balls. The removal efficiency of 99.0 % has been measured.

150. A detailed review of the current and developing mercury technologies and the control effectiveness that can be achieved from these technologies in the U.S. coal-fired power plants has been presented by IEPA (2006). The study has confirmed that depending on several variables, including coal and boiler type, there are a number of control technologies that will achieve 90+ % removal of mercury. Mercury emissions control technology is a rapidly advancing field, with use of halogenated sorbents that are becoming an affordable and effective option for many applications.

7.4.4 Emission control measures suggested for use within the UN ECE LRTAP Convention

151. An assessment of technological developments and the best available techniques for the implementation of the heavy metal emission reduction Protocol of the UN ECE Convention on Long-range Transboundary Air Pollution (Kraus et al., 2006) has recently been prepared. It was found out that the ESPs or FFs operated in combination with FGD and sorbent injection techniques are capable of removing between 75% and 90 % of mercury from the flue gases in coal-fired power plants in the additional presence of selective catalytic reduction. The following conclusions were reached with regard to the least costly retrofit options for the control of mercury emissions from units with ESP or FF:

152. The modification of dry FGD systems by the use of appropriate sorbents for the capture of mercury and other air toxics is considered to be the easiest retrofit problem to solve;
Injection of a sorbent upstream of the ESP or FF. Cooling of the stack gas or modifications to the ducting may be needed to keep sorbent requirements at acceptable levels;
Injection of a sorbent between the ESP and a pulse-jet FF retrofitted downstream of the ESP. This approach will increase capital costs but reduce sorbent costs;
Installation of a semi-dray circulating fluidized-bed absorber (CFA) upstream of an existing ESP used in conjunction with sorbent injection. It is believed that CFAs can potentially control mercury emissions at lower costs than those associated with the use of spray dryers.

7.5 Cost of mercury abatement

7.5.1 Incremental cost of mercury abatement

153. The incremental cost of mercury reduction, i.e. the cost (in US$/kg mercury removed) to achieve a specific reduction is impacted largely by the level of baseline mercury capture exhibited by the existing air pollution control devices (APCD) configuration and coal mercury content. For example, the incremental cost of mercury control will increase when: (1) baseline mercury capture by existing APCD is high; or (2) the coal mercury content is low, because a smaller quantity of mercury is removed from the flue gas for a given level of control. In terms of raw monetary cost, reducing mercury from coal combustion can be quite expensive. The incremental cost of mercury emission reduction varies substantially depending on factors such as the type of coal used, the type of combustion unit, the type of control devices already in place to control other pollutants, the facility configuration, and the percent reductions expected. For example, wet scrubbers installed primarily for mercury have been estimated to cost between US$76,000 and US$174,000 per pound of mercury removed (or between US$168,000 and US$384,000 per kg of mercury removed). This result is very close to the cost of $234,000 per kg of mercury removed, estimated and used in a study of the effectiveness of the UN ECE heavy metals (HM) Protocol and cost of additional measures (Visschedijk et al., 2006).

154. Some years ago, the U.S. Environmental Protection Agency (EPA) had estimated that it would cost between US$67,700 and US$70,000 per pound (or between US$149,300 and US$154,000 per kg) to achieve a 90 percent control level using sorbent injection (US EPA, 2005). Since 1997, Research, Development and Demonstration activities sponsored by the Department of Energy (DOE), vendors and utilities relating to sorbent injection for mercury removal have shown significant advances along with the potential for reductions in overall installation and operational costs. More information on the cost estimates is available from the DOE/NETL's Phase II Mercury Control Technology Field Testing Program (Jones et al. 2006), particularly with regard to the economic analysis of activated carbon injection method. This analysis was conducted on a plant-specific basis, meaning that the economics are dependent on the actual power plant operating conditions and coal properties observed during full scale field testing at each of the power plants taking part in the Program. Mercury control through activated carbon control was analysed. The 20-year levelized incremental cost of mercury control was

found to vary from about US$ 8,400/kg mercury removed to about US$365,000/kg mercury removed.

7.5.2 Mercury emission reduction as a co-benefit of reduction of emission of conventional pollutants

155. At present, it is uncommon for countries to invest in technologies to reduce only mercury from the emissions stream. Instead, countries usually use a multi-pollutant approach, which is much more cost effective. For example, approaches and technologies for controlling conventional air pollutants, including particulate matter, SO_2, and NO_x, typically result in some reduction of mercury emissions as a co-benefit, as mentioned earlier in this chapter. In most countries, mercury controls are contingent upon controls for conventional pollutants, although the degree of the mercury capture by various technologies varies widely. In this context, the incremental cost of adding a mercury reduction effort to a national strategy is much smaller.

156. Major review of information on the costs of abatement for combustion of coal and other economic sectors was carried out within the EU ESPREME (http://espreme.ier.uni-stuttgart.de) and DROPS (http://drops.nilu.no) projects. The annualized investment and operational costs for installations that are used to remove mercury, including ESPs, FFs, FGD, and "add on" measures just for mercury removal are presented in Table 1. These costs are given in relation to the production of 1 MWhe electricity in utility and large industrial boilers. The information on efficiency of mercury removal using these installations is also included in Table 1.

Table 1: Abatement cost for installations used to reduce mercury emissions from coal combustion processes (in US$/ MWhe) in the hard and brown coal combustion sectors– selected technologies from the EU ESPREME project database (http://espreme.ier.uni-stuttgart.de)

Emission control technology	**Mercury reduction (%)**	**Annual costs (US$ 2008/MWhe)**		
		Annual investment costs	**Annual operating costs**	**Annual total costs**
dry electrostatic precipitator (ESP) – medium emission control efficiency	24	0,45	0,90	1,35
fabric filters (FF) – medium emission control efficiency	20	0,46	1,47	1,93
dry ESP – retrofitted from medium to high control efficiency	32	0,92	0,52	1,44
FF+wet or dry scrubbers+sorbent injection – state-of-the-art (BAT)	98	0,72	1,80	2,52
dry ESP + wet or dry scrubber + dry injection -– state-of-the-art	98	2,73	2,40	5,13
electro-catalytic oxidation – emerging method	80	8,55	11,76	20,31
Integrated gasification combined cycle (IGCC) – emerging method	90			20,00

7.5.3 Examples of abatement cost estimates

157. In the United States, EPA promulgated the Clean Air Interstate Rule (CAIR) in 2005, a regulationto reduce criteria air pollutant emissions from power plants,. The U.S. EPA calculated the estimated costs and some of the benefits of that regulation. The CAIR rule is primarily aimed at reducing emissions of SOx and NOx from large coal-fired power plants, but as a co-benefit will result in reductions of mercury emissions. The CAIR rule will achieve the majority of its mercury reductions as a co-benefit from controls for SO_2. Applying SO_2 controls (or other multi-pollutant approaches) are more cost-effective at reducing mercury than direct mercury control. EPA also promulgated the Clean Air

Mercury Rule (CAMR) which was targeted to specifically further reduce mercury emissions from coal-fired power plants. The co-benefits of CAIR were estimated to reduce mercury emissions to 34.5 metric tonnes in 2010; the specific requirements of CAMR were estimated to further reduce mercury emissions to 13.6 tonnes by 2020. This could cost the U.S. electric power industry about US$ 11.3 billion

7.6 Benefits of mercury emission abatement

158. Information on the benefits and costs of reduction of mercury emissions from the coal combustion was recently reviewed by NESCAUM (2005). The NESCAUM study describes the results of a comprehensive assessment of the health benefits of reducing mercury emissions from coal-fired power stations in the United States. It has been anticipated that reductions in mercury emissions from coal-fired power plants decrease methyl-mercury concentrations in fish. A model has been developed assuming that equilibrium currently exists between deposited mercury and fish methyl-mercury concentrations and between fish methyl-mercury concentrations and methyl-mercury exposures to individuals who consume these fish. Changes in the quantity of mercury deposited are assumed to lead to proportional changes in fish methyl-mercury concentrations, assuming that no other factors change. The model accounts for human exposure through commercially and non-commercially harvested fish. Two potential health effects were considered: cognitive abilities and cardiovascular events. The results from epidemiological studies were used to develop association between methyl-mercury exposures in males and increased risks of myocardial infarction and premature mortality. Using a Willingness-to-Pay (WTP) approach it has been estimated that the value of premature fatality is approximately US$ 6.0 million (in 2000 US$) but it was indicated that this value should be taken with caution. The NESCAUM study (2005) also described the possible benefits of the U.S. power plant mercury emission controls in terms of IQ increases in the annual birth cohorts. The predicted annual benefit associated with IQ increases in the annual birth cohort ranged from US$ 75 million to US$ 288 million, estimated within two scenarios related to different emission projection in the U.S. power plants.

159. The societal benefits related to the mercury emission on global scale were estimated in by Pacyna et al. (2008). These benefits were estimated as a difference between the damage costs estimated for the status quo scenario of emission reductions and the EXEC scenario. The two thirds of the societal costs due to mercury pollution are associated with the societal costs due to the mercury pollution of the environment by emissions from coal combustion. Based on preliminary results from this study, the annual social benefits associated with the IQ change due to mercury emission reductions from coal combustion worldwide can be estimated to more than $7 billion.

7.7 Summary of cost and benefits for coal combustion

160. An attempt was made to present the information on types and efficiency of emission reduction technologies for Mercury in the coal combustion sector together with the investment and operational costs of these technologies and compared it with societal benefits due to the implementation of these technologies in the year 2020. The information needed for this comparison is presented in this chapter of the report. The results are presented in Table 2.

Table 2: Abatement costs and benefits in the year 2020 due to the reduction of mercury emissions from coal combustion using various emission control technologies, relative to the status quo scenario of pollution.

Efficiency of mercury emission reduction, %	**Abatement cost** **US$/g mercury abated**	**Societal benefits** **US$/g mercury abated**
0 – 30 % (ESPs or FFs)	100	100
30 – 50 % (ESPs or FFs + FGD)	190	320
50 - 99+% (ESPs or FFs + FGD + sorbent injection)	260	540

161. The benefits were estimated as the difference between the damage costs estimated for the SQ scenario of mercury emissions in the year 2020 (employment of ESPs or FFs only) and respectively the EXEC 2020 emission scenario (application of ESPs or FFs + FGD) and the MFTR 2020 emission scenario (application of ESPs or FFs + FGD + sorbent injection). The damage cost to the society due to exposure to mercury pollution (societal cost) was estimated on the basis of data available from the EU DROPS project (DROPS D5.1 available from Pacyna, 2008). These cost data were obtained in the DROPS project for inhalation of mercury polluted air and ingestion of mercury contaminated food, separately. The cost of $12,500.00 per 1 kg of mercury was accepted for the ingestion pathway.

162. Only neurotoxic impacts through the IQ loss were considered as the main human health end point for mercury. The total damage cost to the society, defined here as the societal cost, is related to IQ loss, through loss of earning, loss of education, and opportunity cost while at school.

163. The investment and operational costs were estimated using 1% discount rate. The comparison in Table 2 indicates that reduction of mercury emissions from coal combustion will result in benefits significantly higher than the cost of abatement. These benefits will be higher when the benefits other than the improvement of IQ are added.

8. To reduce atmospheric emissions of mercury - reduction of mercury emissions from artisanal and small-scale gold mining

8.1 Overall assessment of costs and benefits

164. There are a wide range of measures available within artisanal and small scale gold mining (ASGM) to reduce mercury emissions. An overview of the results is therefore presented after the overall assessments for costs and benefits of reduced emissions from ASGM.

165. *Qualitative Cost Assessment: Variable, ranging from small to large.*

166. There are several technical options available for ASGM. The cost assessments of these measures are linked both to the number of individuals affected by the option and the technical requirements of the options. On this basis, mercury vapour capture in gold shops has small costs due to the relatively small number of gold shops and their fixed locations. The use of retorts in the mining process has medium costs as it affects a larger group of miners and requires educational efforts. Mercury free sluice options are related to medium costs due to the technical requirement of the options.

167. Market mechanisms such as a decrease in gold prices or increase in mercury prices are associated with large costs since they will affect the economic situation for the miners. Micro credits given to

miners to assist in converting their mining activities into mercury free practices (where possible) may result in small costs overall as the credit is paid back.

168. Other mechanisms such as education of best practice and conversion to other livelihoods may incur large costs since they require much greater institutional efforts.

169. *Qualitative Benefit Assessment: Variable, ranging from small to large*

170. The benefit assessments of technical solutions are linked to the number of individuals affected by the option and the decrease in mercury emissions that can result. Mercury vapour capture in gold shops produces medium benefits since there is a large potential for mercury capture from a relatively limited number of emission sources. The use of retorts in the mining process has the potential to produce large benefits if broadly utilised, however the use of retorts has been related to small benefits since the adaptations are smaller in size and variable in quality. Retort use relies on individual mining communities being committed to reducing mercury emissions. The benefit from mercury free sluice solutions are related to large benefits since no mercury is required, although this benefit estimate may be reduced by mining situations where it is not feasible to use mercury free sluice solutions.

171. Market mechanisms such as decreases in gold prices or increases in mercury prices are estimated as giving small benefits since the price difference between gold and mercury is very large. This price difference reduces the motivation to altered mining technologies or reduced mining activities. Micro credits provided to facilitate the move to mercury-free technology may be related to large benefits since they would help in phasing out mercury use, however this may not be universally feasible.

172. Education is related to small benefits on a global scale since education needs to be linked to other options, such as access to technology, and market mechanisms in order to be effective. It is difficult to quantify the effects of education on community groups, where increased awareness of the hazards of mercury may result in more significant behaviour changes. Conversion to other livelihoods for miners is related to small benefits since other potential miners are likely to take the place of the miners moving to other sources of livelihood.

173. For all the measures aimed at abating the release of mercury from ASGM activities, the benefits are both local and global in their nature. In relation to other type of emission sources, the benefits from reducing mercury use and release in ASGM has a stronger emphasis on local benefits due to the reduction of high direct exposure to mercury air emissions and water pollution affecting the miners and the local population.

174. An overview of the cost-benefit of strategies to reduce mercury emissions is presented in Table 3.

Table 3: Overview of the cost-benefit of strategies to reduce mercury emissions

Strategy	*Preliminary Qualitative Cost Assessment*	*Preliminary Qualitative Benefit Assessment*
Technological solutions		
- Mercury vapour capture in gold shops	SMALL	MEDIUM
- Retort use in mining	MEDIUM	SMALL
- Sluice solutions	MEDIUM	LARGE
Market Mechanisms		
- decrease in gold price	LARGE	SMALL
- increase in mercury price	LARGE	SMALL
- micro credit to clean technologies	SMALL*	LARGE*
Other mechanisms		
- Education	LARGE	SMALL
- Conversion to other livelihoods	LARGE	SMALL

- No evaluated experiences on ASGM, but pilot studies are performed

8.2. Small Scale Gold Mining as a source of mercury emissions

175. The demand for mercury in Small Scale and Artisanal Gold Mining (ASGM) was for the year 2005 estimated to 1000 tonnes. The major part (650 to 1000 tonnes) of these 1000 tonnes is not recycled but rather released via gold mining processes to air and water, thereby causing adverse environmental effects and effects on human health. The environmental and human health effects are more of a local nature in comparison to other types of mercury emissions, given the large impact on the gold miners, the local population and their local environment. Mercury pollution from ASGM cause global pollution effects due to the emissions to air from combustion of mercury in the gold mining process, but what is characteristic for ASGM (in contrast to other mercury emission sources) is the high local human exposure of highly concentrated mercury vapour in air and mercury residual in water. This extreme exposure is related to a number of medical conditions not common for other types of "more controlled" mercury emissions. Emissions from ASGM are responsible for approximately one third of all anthropogenic mercury emissions globally. ASGM involves some 10 to 15 million miners and produces roughly 20 to 30 % (500 - 800 tonnes per year) of the global gold production (Telmer 2007).

8.3. Mercury abatement efficiency and costs

176. There are a number of technologies available to reduce the use or release of mercury associated with ASGM. The use of mercury vapour capture technologies in gold shops is estimated to be quite efficient since it involves relatively large scale operations and allows for increased income for the users of the technology. The estimated costs are relatively low. A quick estimate is a cost less than US$ 19 / kg reduced mercury emission (not considering education or disposal costs). Telmer (2008) indicate that the installation of vapour capture equipment in a gold shop would cost US$ 35 and capture 90 % of the mercury vapour.

177. The use of mercury retorts by miners is based on information and education and there are a vast number of miners in need of education, so the use of retorts is estimated as costly, although the unit cost of each retort is low. The efficiency of the measure depends on the application of the retorts.

178. The use of some sluices can be advocated since experiments indicate a relatively high efficiency in recovering gold (Hylander et al. 2007) under certain circumstances. It is also a mercury free alternative, which further increases the efficiency. The costs associated with using the studied slurry techniques are stated as being more cost efficient than using mercury amalgamation techniques (Hylander 2007). However, investments will be required.

179. There are other more technology independent options that could decrease the mercury emissions from ASGM. A decrease in gold prices could result in a reduction in gold mining and mercury use. Given a recent price relation between gold and mercury of 1:1000 (ranging between 1:1650 to 1:125, Telmer 2008), it is quite plausible that it would require an extremely large reduction in gold price before gold production via ASGM technologies would become less profitable than alternative income sources for the community. Furthermore, if there were to be a large decrease in gold price, many poor populations would become even poorer.

180. If the prices for mercury were to increase, the demand should correspondingly decrease. Veiga and Baker (2004) indicate that mercury constitutes 1 - 30 % of the gold production costs for ASGM using mercury amalgamation techniques. All in all, although mercury is very cheap compared to the price of gold, the literature and experience supports that high mercury prices results in reduced mercury losses from ASGM. UNEP (2004) and Hylander (2007), for example, indicate a large demand effect of high mercury prices.

181. Micro credits have proven themselves as very effective as a tool to reduce poverty in other circumstances in the world (Yunus 2006, Grameen Bank). This could provide the opportunity to the gold miners to increase their long term thinking when engaging in gold mining. Furthermore, given that this is a loan, implementation costs can be reduced as loans are repaid.

182. Education has been indicated as inefficient if not followed by increasing mercury prices (EC DG-ENV 2006). However, education of some sort will be needed for the application of any technology or other measure since the current market conditions for miners still encourage the use of mercury amalgamation. Using previous experiences, an estimate is that US$ ~1000 million would be needed to educate 10 million miners in the use of retorts. Mercury would still be used by these miners, although the emissions would be lower.

183. Conversion to other livelihoods for miners is most likely a very ineffective abatement option. To convert the livelihood of miners will have almost zero benefit since potential miners can fill the gap as long as there are high profits to be made and few alternative occupations in the regions where ASGM take place. A comparison using African conditions indicates that 42 % of the people in sub-Saharan Africa have earnings below US$ 1 / day, while miners earn US$ 3 - 15 per day. Similar estimates can be seen in many parts of the world (Handelsman and Veiga 2006).

8.4. Benefits of mercury emission abatement

184. Mercury vapour capture technology in gold shops is a relatively potent abatement solution both since the vapour can be condensed and re-sold as mercury and also since the solution is oriented towards the relatively large scale gold shops (large scale when compared to single person miners). Some 90 % of the emissions from gold shops can be reduced by this technology.

185. The reduced emissions from using retorts are uncertain and depend on local conditions.

186. In a 2-year project community mining groups have been trained and are purchasing and using retorts, each of which costs about $5 when purchased in bulk. 500 miners have been trained and to date, upwards of 80 percent, as self-reported by the miners, are using the retorts. A retort has a maximum potential of capturing 90 % of the mercury vapour A rough estimate, assuming that 10 million miners are using 1000 tonnes of mercury (10 kg / person year) indicates that mercury use could be reduced by around 7 kg mercury per person per year. The costs following this effort are constituted of US$ 5 per retort and US$ 100 per person for education (based on EU experience cited above), which gives a final rough estimate of US$ 15 / kg mercury captured in the retorts during the first year of use. The duration of the training efforts, the retort efficiency and the lifetime of the retort are central parameters for the cost estimates. The costs of training ($100 per person) could be averaged over five years, provided miners were continuing to use the same types of retorts, leading to an approximate cost of $3/kg mercury per year for those five years.

187. The use of modern sluices is the one of the technologies that is mercury-free. The use of mercury-free technology is more efficient than reducing emissions from mercury, which is the reason why the benefit estimate is higher than other ASGM technologies where mercury is used but the emissions are reduced.

188. Given a recent price relation between gold and mercury of 1:1000, it would require an extremely large price reduction in gold before gold production via ASGM technologies would become less profitable than alternative income sources for the community. Another effect is that the disposable income would become even smaller for the miners and their community. If mercury price was increased, the income could become smaller for the miners, resulting in a poorer financial situation, although increasing mercury prices may provide an incentive for miners to use less mercury (by using processes to concentrate the ore prior to amalgamation), or to ensure efficient capture and recycling of mercury.

189. The implementation of suitably designed micro credits could encourage the use of mercury-free technologies which increases the potential benefit of this abatement option, since no use of mercury has a higher benefit than control of mercury emissions via technical solutions.

190. Education has been indicated as inefficient if not followed by increasing mercury prices (EC DG-ENV 2006). The benefit estimate is very uncertain and variable, given that almost all of the above mentioned abatement options will require some sort of education to introduce the option. For education efforts aimed at increased awareness and not specified towards any specific abatement option, the benefit estimate is therefore considered as small.

191. Conversion to other livelihoods for miners can be efficient for the miners considered for this action and their relatives. If other miners will fill the gap of the miners that have been converted into other occupations, this option will have zero effect on the mercury emissions. In fact, as new miners have not benefited from training and experience, there is potential for mercury emissions to rise.

9. Reducing atmospheric releases of mercury - Reduction of mercury from emissions from industrial processes, including use as a catalyst, by-production, contamination of component materials, and heat production

9.1. Overall assessment of costs and benefits

192. *Qualitative Cost Assessment: Medium to Large*

193. *Cost Categories: Capital costs, operating costs*

194. *Qualitative Benefit Assessment: Medium to Large mercury emission reduction both globally and locally.*

9.2. Industrial processes as a source of mercury emissions

195. Industrial processes contribute about 25 % to the total emissions of anthropogenic mercury to the atmosphere.

196. Emissions from non-ferrous and ferrous metal industry are estimated to contribute about 10 % to the total emissions. With regard to the mercury emissions from non-ferrous metal production, their amounts depend mainly on: 1) the content of mercury in non-ferrous metal ores used mostly in primary processes or scrap used in secondary non-ferrous production, 2) the type of industrial technology employed in the production of non-ferrous metals, and 3) the type and efficiency of emission control installations.

197. The content of mercury in ores varies substantially from one ore field to another (e.g. Pacyna, 1986, UN ECE, 2000) as does the mercury content in scrap. The mercury emissions from primary production using ores in non-ferrous smelters are between one and two orders of magnitude higher that the mercury emissions from secondary smelters with scrap as the main raw material, depending on the country. Pyro-metallurgical processes in primary production of non-ferrous metals, employing high temperature roasting and thermal smelting emit mercury and other raw material impurities mostly to the atmosphere. Non-ferrous metal production with electrolytic extraction is responsible more for risks of water contamination.

198. Major thermal non-ferrous metal smelters in developed countries employ ESPs and FGDs, working with efficiencies comparable with those for noted for energy production. This information has been obtained by the authors of the report (Pacyna et al. 2001) from:

a. Cominco Ltd in Canada,
b. Hudson Bay Mining and Smelting Co. Limited in Canada,
c. Kennecott Utah Copper Corporation in the United States,
d. Huttenwerke Kayser AG in Germany,
e. Berzelius Metall GmbH in Germany,
f. Norddeutsche Affinerie in Germany, and
g. Metaleurop Weser Blei GmbH in Germany.

199. More details on individual non-ferrous metal works are available from metal Bulletin Books (see also www.icmm.com).

200. Among various steel making technologies the electric arc (EA) process produces the largest amounts of trace elements and their emission factors are about one order of magnitude higher than those for other techniques, e.g., basic oxygen (BO) and open hearth (OH) processes. The EA furnaces are used primarily to produce special alloy steels or to melt large amounts of scrap for the reuse. The scrap which often contains trace elements including mercury, is processed in electric furnaces at very high temperatures resulting in volatilization of these elements. This process is similar from the point of view of emission generation to the combustion of coal in power plants. Much less scrap is used in other furnaces, where mostly pig iron (molten blast-furnace metal) is charged. It should be noted, however, that the major source of atmospheric mercury related to the iron and steel industry is the production of metallurgical coke.

201. The primary sources of mercury emissions from portland cement manufacturing contribute about 9 % to the total anthropogenic emissions of this element. These emissions are generated in the kiln and preheating/pre-calcining operations. The kiln operations consist of pyro-processing (thermal treatment) of raw materials which are transformed into clinkers. Raw material processing differs somewhat for the

wet and dry processes. Mercury is introduced into the kiln with fuels such as coal and oil which are used to provide energy for calcination and sintering. Other fuels, such as shredded municipal garbage, chipped rubber, petroleum coke, and waste solvents are also being used frequently.

202. Occasionally, building companies mix cement with fly ash from coal combustion in proportion about 3:1 in order to produce concrete. Fly ash may contain mercury through the condensation of gaseous mercury on fine fly ash particles in the flue gas before the collection of fly ash on de-dusting devices, such as ESPs or FFs (Pacyna, 1980). However, it is difficult to assess how much of mercury enters the environment through this pathway.

203. Heat is produced in large and medium size central heating plants, as a co-generation product in large electric power stations, industrial boilers and small residential and commercial furnaces. Large industrial plants generate their own electric power or process steam. The process of generation of emissions of mercury from these plants is similar to the one for emissions from coal and oil combustion in electric utility plants, discussed in Chapter 2 in this report, and emission controls are also similar. The main difference is brought by the type of boiler employed, which is often a stoker-type boiler. The pulverized and cyclone boiler units are generally associated with larger industrial complexes and are similar in design to those used in electric utilities.

204. Commercial and residential furnaces are mainly used for space heating. Small stoker-type boilers and hand-fired units are still used in many regions of the world. Emission control equipment is not generally used in these small furnaces.

9.3. Mercury abatement efficiency and costs

205. Large non-ferrous smelters use high efficiency air pollution control devices to control particle and sulfur dioxide emissions from roasters, smelting furnaces, and convertors (e.g. Pacyna et al., 1981; Pacyna et al., 2001). ESPs are the most commonly used devices for removal of particles. Control of sulfur dioxide emissions is achieved by absorption to sulfuric acid in the sulfuric acid plants, which are commonly a part of the smelting plants. Mercury is emitted mostly in a gaseous form and therefore, the ESPs are not very effective in removal. The element does not end up in sulfuric acid plants and is instead emitted to the atmosphere from the smelter stacks. The amount of these emissions depends on the content of mercury in the ore. This content varies substantially from one ore field to another. Only limited information has been gathered on mercury emission rates from non-ferrous smelters by the U.S.EPA (1993).

206. Mercury can be emitted to the atmosphere during the production of metallurgical coke, which is used in iron and steel industry. ESPs or FFs and less frequently wet scrubbers are used in the coke production plants to control emissions, particularly those generated during quenching. This process is performed to cool down the coke and to prevent complete combustion of the coke upon exposure to air. Although no data are available for the performance of the ESPs or FFs in coke production plants it is expected that mercury removal is limited (U.S.EPA, 1993).

207. The U.S. EPA has some experience with quantifying the costs and benefits of reducing mercury emissions from various industrial sources. One such industry is secondary steel production. This category is a significant source of mercury air emissions largely because mercury-containing switches are in the scrap metal (such as cars) used to make steel. In the United States, a program was established in 2006 called the National Vehicle Mercury Switch Recovery Program (NVMSRP). The NVMSRP, along with a few state mercury switch programs, will reduce mercury emissions by about 34 tonnes over the next 15 years, which represents the mercury content in approximately 61 million switches. The program is designed to remove mercury-containing switches from scrap vehicles before they are recycled in secondary steel mills, therefore preventing mercury emissions At this time, the precise cost-effectiveness of this program is unknown, although components of the costs include: outreach and education, design efforts which are typically do not require significant ongoing monetary investment. However, the voluntary effort to remove switches provides an incentive of about US$1.00 per switch. While this may not reflect the actual cost of removing the switch (some states have proposed incentives of up to US$7.00 per switch), it still costs significantly less than installing end-of-pipe controls to capture mercury at the furnace. In December of 2007, EPA also promulgated the Electric Arc Furnace Rule which codifies and builds upon the voluntary program (EPA, 2007).

208. With regard to chlor-alkali plants, the EPA promulgated an emissions standard based on maximum control technology (MACT) in December 2003 to limit mercury emissions from this industry. The MACT rule requires controls and emissions limits for process vents and relatively stringent work practice standards or a cell room monitoring program to minimize fugitive emissions from the cell rooms. The total estimated capital cost of the final rule for the nine mercury cell chlor-

alkali plants was around US$1.6 million, and the total estimated annual cost is about US$1.4 million per year. Plant-specific annual costs in our estimate range from about US$130,000 for the least-impacted plant to about US$260,000 for the worst-impacted plant. The final rule will reduce mercury air emissions from existing emission points within mercury cell chlor-alkali plants by 675 kg per year, a 74 percent reduction from current levels. The final rule also requires rigorous work practice standards such as periodically washing down work floors and covering waste containers. These requirements will reduce mercury emissions from so called "fugitive sources" throughout the plants. Although EPA is not able to accurately quantify the reductions associated with these work practice standards, these requirements will reduce mercury air emissions industry wide. By any accounting, the costs of implementing the MACT rule are significantly less than facility conversion to non-mercury cell technologies.

209. Major review of information on the costs of abatement for combustion of coal and other economic sectors was carried out within the EU ESPREME (http://espreme.ier.uni-stuttgart.de) and DROPS (http://drops.nilu.no) projects. The annualized investment and operational costs for installations that are used to remove mercury, including ESPs, FFs, FGD, and "add on" measures just for mercury removal are presented in Table 5. These costs are given in relation to the production of 1 tonne of specific production, indicated as specific activity indicator. The information on efficiency of mercury removal using these installations is also included in Table 6.

Table 6: Abatement cost for installations used to reduce Mercurymercury emissions from various industrial processes (in US$ /tonne of specific production- SAI) – selected technologies from the EU ESPREME project database (http://espreme.ier.uni-stuttgart.de)

Sector	Specific activity indicator (SAI)	Emission control technology	Mercury reduction (%)	Annual costs (US$ 2008/SAI)		
				Annual investment costs	Annual operating costs	Annual total costs
Sintering	tonne sinter	dry electrostatic precipitator (ESP) – medium efficiency of emission control	5	0,10	0,05	0,15
		dry ESP – optimized	70	0,21	0,20	0,41
		virgin activated carbon injection (SIC)+FF – optimized	80	2,10	1,12	3,22
		calcium hydroxide-impregnated adsorbents (SICa) – emerging method	100	1,05	1,24	2,29
Primary lead	tonne primary lead	dry ESP – medium efficiency of emission control	5	0,06	0,04	0,10
		fabric filters (FF) – state-of-the -art	10	0,12	1,12	1,24
		virgin activated carbon injection (SIC)+FF+FGD – optimized	90	2,48	1,32	3,80
Primary zinc	tonne primary zinc	dry ESP – medium efficiency of emission control	5	0,10	0,06	0,16
		fabric filters – state-of-the-art	10	4,50	1,12	5,62
Primary copper	tonne primary copper	fabric filters – medium efficiency of emission control	5	1,80	13,80	15,60
		fabric filters – state-of-the-art	10	3,87	25,65	29,52
Secondary lead	tonne secondary lead	dry ESP – medium efficiency of emission control	5	0,10	0,06	0,16
		fabric filters – state-of-the-art	10	6,75	1,12	7,87
Secondary zinc	tonne secondary zinc	dry ESP – state-of-the-art	5	0,10	0,06	0,16
		fabric filters – state-of-the-art	10	0,12	1,42	1,54

Sector	Specific activity indicator (SAI)	Emission control technology	Mercury reduction (%)	Annual costs (US$ 2008/SAI)		
				Annual investment costs	Annual operating costs	Annual total costs
Secondary copper	tonne secondary copper	dry ESP – state-of-the-art	5	10,89	15,86	26,75
		fabric filters – state-of-the-art	10	6,64	43,97	50,61
Cement production	tonne cement	fabric filters – medium efficiency of emission control	5	0,20	0,22	0,42
		fabric filters – optimized	98	0,39	0,38	0,77
		wet FGD – optimized	90	1,35	0,45	1,80
Coke production	tonne coke	use of raw materials with low HM content – optimized	5	0,00	0,02	0,02
		fabric filters – medium efficiency of emission control	5	0,21	1,65	1,86
		fabric filters – optimized	5	0,46	3,08	3,54
		dry ESP – medium efficiency of emission control	5	0,76	1,11	1,87
		wet FGD – medium efficiency of emission control	30	2,80	1,91	4,71
		wet FGD – optimized	40	3,04	2,79	5,83
		dry ESP – optimized	70	1,40	1,57	2,97
Iron and steel foundring	tonne cast iron	fabric filters – medium efficiency of emission control	5	10,80	82,77	93,57
		dry ESP – medium efficiency of emission control	5	38,10	55,47	93,57
		fabric filters - retrofitted from medium method to state-of-the-art	98	12,46	71,10	83,56
		dry ESP – optimized	70	69,80	78,97	148,77
Pig iron production	tonne cast iron	fabric filters – medium efficiency of emission control	5	0,20	0,75	0,95
		dry ESP – medium efficiency of emission control	5	1,53	2,22	3,75
		dry ESP - retrofitted	72	1,28	0,94	2,22
		dry ESP – optimized	70	2,79	3,16	5,95
Basic oxygen furnace steel	tonne steel	dry ESP – medium efficiency of emission control	5	1,20	3,00	4,20
		wet scrubber Venturi – optimized	8	5,68	0,54	6,22
		dry ESP – optimized	70	4,32	4,50	8,82
Electric arc furnace steel	tonne steel	fabric filters – medium efficiency of emission control	5	0,21	1,65	1,86
		dry ESP – medium efficiency of emission control	5	0,76	1,11	1,87
		fabric filters - retrofitted	98	0,26	1,42	1,68
		210. dry ESP– optimized	70	1,40	1,57	2,97

211. Major assessment of costs and environmental effectiveness of options for reducing mercury emissions to air from small scale combustion installations, SCI, (<50 MWth) has been prepared for the European Commission by Pye et al. (2006). It was concluded that:

> The most cost-effective options were preventive options (e.g. options prior to combustion to minimize emissions), such as coal washing and fuel switching. Such options require the use of a better quality, cleaner fuel within the same fuel type, or the switching to an alternative fuel with lower emissions. Another preventive option is reduction in energy consumption through energy efficiency; Only limited technical abatement options (such as removal of mercury from flue gases after combustion) were identified for SCI.

212. An assessment of abatement costs for reduction of heavy metals, including mercury within various industries was carried out for the heavy metal emission reduction Protocol of the UN ECE Convention on Long-range Transboundary Air Pollution (Visschedijk et al., 2006). The results of this assessment are similar to the data presented in Table 6.

9.4. Benefits of emission reductions

213. Information on monetary valuation of environmental and human health benefits related to the reduction of mercury emissions from individual industrial sources is largely missing in the literature.

214. Societal benefits related to the decrease of the 2005 mercury emissions from industrial sources worldwide until the year 2020 are estimated by Pacyna et al (2008) as a part of an assessment of socio economic costs of continuing the status quo of mercury pollution from all major anthropogenic sources. The social benefits were estimated as a difference between the societal costs (damage costs) related to the emission reductions calculated for the scenario assuming the status quo of environmental pollution between the years 2005 and 2020 and the emission reductions projected in the scenario where application of modern emission control devices is employed.

215. For the metal industry and cement manufacturing preliminary results suggest an annual damage costs to society due to ingestion of mercury contaminated food in the year 2020 can be as high as US$ 5 600 million along the assumptions defined for the status quo scenario relating to pollution of environment by mercury since 2005 and up to US$ 1 900 million along the assumptions defined for the extended emission control scenario (UNEP, 2008). The damage costs to society due to inhalation of mercury polluted air were estimated insignificant compared to the damage costs due to ingestion. Thus, the societal benefits due to reduction of mercury emissions from metal industry and cement manufacturing in the year 2020 were estimated to be about US$ 3 700 million.

10. To address mercury containing wastes and remediation of contaminated sites - Reduction of generation of wastes that contain mercury

10.1. Overall assessment of costs and benefits

216. *Qualitative Cost Assessment: Variable depending on the management technique such as incineration and land filling*

217. *Qualitative Benefit Assessment: very high relative to the abatement costs if management is in place*

10.2. Mercury abatement efficiency and costs

218. A number of sources of waste contain mercury. These sources may differ from one region to another and the quantity of waste-mercury from different sources may be correlated with life style and the level of economic development in the different countries and regions as well. Since the sources are different and the emissions from these sources are local and region specific, the costs to reduce generation of wastes that contain mercury and the measures as well as their implementation to reduce the emissions from these sources differ depending on whether the source is in a developed country or in a less developed one.

219. Table 7 brings together some sources of mercury containing waste generated both in developed countries (DC) and in less developed countries (LDC) where most of the sources are related to certain level of economic development.

Table 7: Examples of different sources of waste

Wastes from natural gas purification and transportation - wastes containing mercury
Metal-containing wastes other than those mentioned in batteries and accumulators/wastes from the manufacture, formulation, supply and use (MFSU)/manufacture, formulation, supply and use/of salts and their solutions and metallic oxides/ - wastes containing mercury
End-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance - components containing mercury
Batteries and accumulators - mercury-containing batteries and lamps and electronic devices
Construction and demolition wastes - construction and demolition wastes containing mercury
Wastes from natal care, diagnosis, treatment or prevention of disease in humans – amalgam waste from dental care
Separately collected fractions - fluorescent tubes and other mercury-containing waste

Source: adapted from: http://ec.europa.eu/environment/chemicals/mercury/doc/czech_rep_1.doc

220. In order to reduce generation of waste that contains mercury in developed countries different policy instruments including regulations, market based instruments as well as information are used. The reason why these policy instruments are developed is based on the fact that mercury in waste is leading to externalities (both ecological and health) where the damage costs may be very high as in the case of ingestion of fish containing mercury and the implied reduction of IQ in the population of infants. Hence, the policy instruments have led to the implementation of different measures and waste management of wastes containing mercury such as recycling, land filling and incineration (for more detail on related to the costs of these measures see section 7). However, whilst the use of regulations and market based instruments have led to different technical measures that are moderate in the case of landfills and high in the case of incineration (which has led in some cases to the export of hazardous waste to LDC), the most cost effective measures are non technical being the results of good information highlighting the consequences of mercury emissions on the environment and human health.

221. Manydeveloping countries lack well formulated guidelines and policy structures regarding waste in general and waste containing mercury in particular. However, whilst both technical and non technical measures are used in developed, the measures in developing countries are on a small scale and may be relatively uncontrolled. Uncontrolled dumping of wastes on outskirts of towns and cities has created overflowing landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also because they have serious environmental implications (http://cat.inist.fr/?aModele=afficheN&cpsidt=2384293).

222. Abatement costs after policy instruments are in place may be high for technical measures and if transaction costs including monitoring are included in the estimations. However, costs to reduce waste containing mercury may be low and cost effective if the policy instruments are based on guidelines and information.

223. At the global level, the international community is working to strengthen legislation on the use, movement and disposal of toxic and hazardous waste (http://www.marketresearch.com/product/display.asp?productid=1470786). An example of international work is the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (in force since 1992). These works may lead to lower global environmental and health damage.

11. To address mercury containing wastes and remediation of contaminated sites - Promotion of separate collection and treatment of mercury-containing wastes

11.1. Overall assessment of costs and benefits

224. *Qualitative Cost Assessment: small to medium, at least in developed countries*

225. *Qualitative Benefit Assessment: relatively large*

11.2. Mercury abatement efficiency and costs

226. Outside the industrial sector which is responsible for high emissions/releases of mercury, several other products include mercury which should be managed appropriatelysuch as by recycling in order to prevent emissions of this pollutant. Some of the products containing mercury and which can be recycled are shown in Table 8.

Table 8: Some products containing mercury

Fluorescent bulbs:	All fluorescent bulbs typically contain 10-40 milligrams of mercury (.01 - .04 grams of mercury). Nonetheless, these bulbs use up to 50-75% percent less electricity than incandescent bulbs, making them the environmentally preferred choice. Remember to keep fluorescent bulbs out of the trash, avoid breakage and contact a recycling service to remove them.
Thermometers	Mercury thermometers can be identified by the silver colored liquid in the bulb. -Thermometers typically contain 0.5 - 0.7 grams of mercury. Large thermometers can have as much as 3 grams of mercury. Alternatives: Replace with digital thermometers or alcohol (red bulb) thermometers.
Thermostats	Non-electronic thermostats contain an average of 5.25 grams of mercury. Alternatives: Replace with electronic thermostats.
Other sources of mercury	
Button cell batteries (some types) - like those used in watches	
Dental fillings	
-Mercury switches - silent light switches and tilt switches, found in automotive trunk and hood lights, clothes irons, and space heaters	
-Old pesticides, fungicides, paint	
-Electronic devices	
-Different equipment at different public units e.g. drinking water systems	

Source: http://www.wastecap.org/wastecap/commodities/mercury/mercury.htm

227. The use of electronic devices has proliferated in recent decades both in developed and developing countries, and proportionately, the quantity of electronic devices, such as PCs, mobile telephones and entertainment electronics that are disposed of is growing rapidly throughout the world. In 1994, it was estimated that approximately 20 million PCs (about 7 million tonnes) became obsolete. By 2004, this figure increased to over 100 million PCs. Cumulatively, about 500 million PCs reached the end of their service lives between 1994 and 2003. 500 million PCs contain approximately 287 tonnes of mercury (Puckett and Smith, 2002). This fast growing waste stream is accelerating because the global market for PCs is far from saturation leading to proportional increase of electronic waste (Culver, 2005).

228. To limit emissions of mercury several techniques may be used (as discussed above). Some of these techniques are presented in Table 9. However, where mercury containing products are used, promotion of separate collection and treatment of mercury-containing waste is likely to be most effective in limiting releases of mercury. Whilst promotion may give results in the developed world, this strategy may be more challenging in the developing world where there is often no differentiation between municipal, hazardous and medical waste in terms of applied techniques or achievable emission limits.

Table 9: Some mercury management techniques

Sector	**Best available technology (BAT)**	**Emerging techniques**
Municipal, medical and hazardous waste incineration	-Separate collection and treatment of mercury containing wastes -Substitution of mercury products -Sorbent injection -FGD -Carbon filter beds -Wet scrubber with additives -Selenium filters -Activated carbon injection prior to the ESP or FF -Activated carbon or coke filters -Selective catalytic reduction (SCR) -Co-incineration of waste and recovered fuel in cement kilns -BAT for cement kilns -Co- incineration of waste and recovered fuel in combustion installations -Avoid Mercury entering as an elevated component of the secondary fuel -Gasification of the secondary fuel -Injection of activated carbon -BAT for combustion installations	Heavy metal evaporation process Hydro-metallurgical treatment + vitrification Municipal waste incineration PECK combination process

Source: http://www.unece.org/env/lrtap/TaskForce/tfhm/third%20meetingdocs/Summary_BAT_060407.doc

229. Nevertheless, promotion of mercury management is warranted at levels including households, industries and the public sector. However, except technical measures that may be used to reduce emissions of mercury, other measures such as substitution would be more cost effective. Table 10 shows some examples of substitution measures related to public water system unit in the US, where the costs, depending on the measure, are quite low.

Table 10: Examples of strategies using mercury-free alternatives in public water system units in the US, where abatement costs, depending on the measure, may be quite low.

Switch and relay alternatives	
Mechanical switch (metallic ball, snap switch, microswitch)	Uses a solid such as metallic ball that moves back and forth completing or breaking the circuit. Price for float switch replacement runs from US$ 25 to US$ 250. Price for free-floating float with inverter microswitch ranges from US$ 93 to US$ 175. Price for tilt switch ranges from US$ 1 to US$ 25.
Magnetic dry reed/magnetic switch	Metal reeds are drawn together completing the circuit in the presence of a permanent magnet. Prices for magnetic reed float switch range from US$4 to US$ 600 depending on use and features.
Continuous level transmitters	Use relay switches in a series. Price ranges from US$ 450 to over US$ 1200 depending on length. Allows for continuous data transmission capability.
Sensor alternatives	
Submersible pressure transmitter or transducer	The sensor probe is suspended by cable from the top of the tank and continuously measures pressure based on the water level above the sensor. Suppliers and manufacturers contacted report that these are low maintenance, come in no corrosion (titanium) models, and are easy to install. Prices range from US$ 350 to US$ 800.
Electronic pressure transmitter (nonsubmersible)	The transmitter is connected to plumbing at the bottom of the tank and measures pressure based on the water level above the sensor. Suppliers and manufacturers report that these are no or low maintenance, weather proof, and easy to install. These sensors measure the exact water level as opposed to the presence or absence of water at a certain level. Costs range from US$ 560 to US$ 900.
Ultrasonic, sonic, radar	Sound waves or radar travel down the measurement tube and reflect against the surface of the tank contents before returning back to the receiver. Electronics measure the time and calculate water level. Prices range from US$ 200 to over US$ 1000 depending on features and accessibility.

http://www.mass.gov/dep/water/drinking/mercbmp.pdf

230. The costs of mercury management may be small to medium in the case of developed countries, for examples costs of collection, transportation and recycling of switches in the US ranges between US$ 0.004 and $1.0. Some lesser developed and developing countries import considerable quantities of electronic waste. The Figure 3 below depicts the main electronic waste traffic routes in Asia.

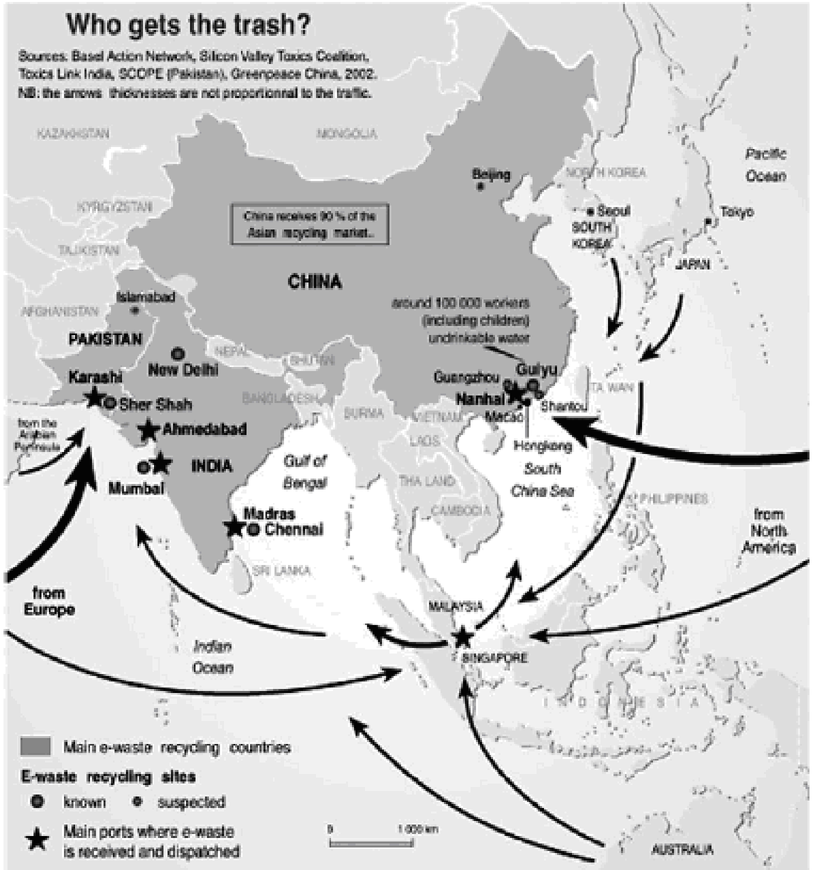


Figure 3: Main electronic waste traffic routes in Asia.

231. The benefits of separate collection and treatment of mercury containing waste are relatively large compared to the costs of abatement, including both technical and substitution measures.

12. To address mercury-containing waste and remediation of contaminated sites - Reduction of mercury emissions to air from medical, municipal, and hazardous waste incinerators and reduce migration and emission of mercury from landfills

12.1. Overall assessment of costs and benefits

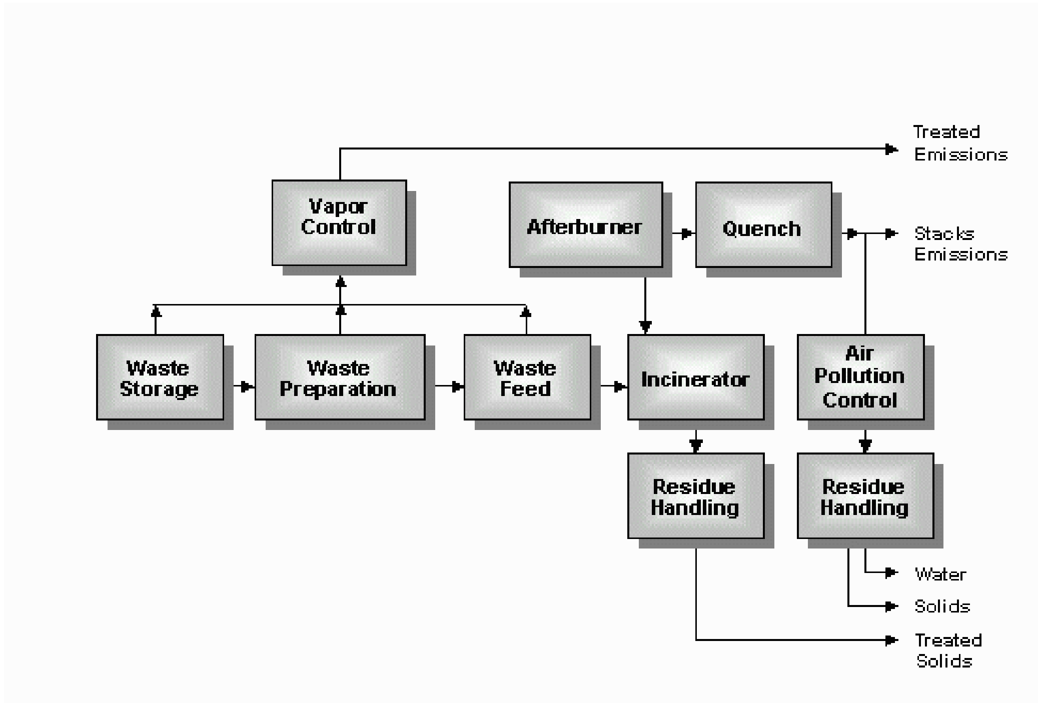
232. *Qualitative Cost Assessment: Large to medium in the case of incineration and land filling, respectively*

233. *Qualitative Benefit Assessment: The benefits of incinerating or land filling (although they are high to medium, respectively), they are very large compared to the total costs of these management technologies.*

12.2. Mercury abatement efficiency and costs

234. Comparing of the external effects of incineration and land filling different studies revealed that the cancer risk from living near a landfill was about 100 times that of living near an incinerator. Furthermore, criticisms leveled against incineration arise from its history of releasing dioxins and furans. Consequently, for incinerators to provide an effective means of reducing the bulk of municipal waste in general, it is important that they do not emit harmful gases, compounds and particles. This is why the fulfillment of these requirements is correlated with high investment and maintenance costs.

235. For properly operated incinerators, the destruction and removal efficiency exceed the 99.99% requirement for hazardous waste and can be operated to meet the 99.99% requirement for PCBs and dioxins. Off gases and combustion residuals generally require treatment (http://www.frtr.gov/matrix2/section4/D01-4-23.html). Figure 4 below is a schematic cradle to grave illustration of how waste can be managed using an incinerator.



Source: http://www.frtr.gov/matrix2/section4/D01-4-23.html

Figure 4 : A schematic cradle to grave illustration of how waste can be managed using an incinerator.

236. When it comes to costs related to incinerator and waste treatment, Table 11 shows an example based on different scenarios and the type of waste in question. The Table represents estimated costs to apply incineration technology at sites of varying size and complexity where not only mercury is managed but other hazardous pollutants as well, e.g. dioxins.

Table 11: Cost of incinerator

Incinerator	Scenario A	Scenario B	Scenario C	Scenario D
	Small site		**Large site**	
	Easy	Difficult	Easy	Difficult
Cost per m^3	$1047	$1540	$914	$1399

Source: http://www.frtr.gov/matrix2/section4/4-23.html

237. As shown in the Table 11 costs differ depending on whether the site is small or large. These costs range between $1047 in the case of a small site and $1399 for the difficult case when the site is large. However, for costs specific to mercury, Table 12 shows both investment and operating costs while investing in an incinerator.

Table 12: Investment and operating costs while investing in an incinerator.

Sector	Emission control technology	Mercury reduction (%)	Annual costs (US$ 2008/ tonne waste)		
			Annual investment costs	Annual operating costs	Annual total costs
Waste incineration and cremation processes	wet scrubber (wSC) with alkaline addings – medium efficiency if emission control	20	0,12	0,08	0,20
	waste separation – medium	60	0,60	0,60	1,20
	dry ESP – optimized	70	1,84	6,99	8,83
	ESP+wet scrubber+activated carbon with lime+FF – optimized	99	2,31	2,48	4,79
	two-stage scrubber+wetESP – optimized	90	2,31	1,82	4,13
	virgin activated carbon injection (SIC)+FF – optimized	80	2,19	4,02	6,21
	virgin activated carbon injection (SIC)+venturi scrubber+ESP – optimized	95	5,25	6,15	11,40
	virgin activated carbon injection (SIC)+venturi scrubber with lime milk+caustic soda+FF– optimized	99	5,78	7,08	12,86

238. Investment and maintenance costs of appropriate landfills are relatively lower. Landfill controls can be implemented to limit mercury release and will also benefit management of many other hazardous wastes. As an example, the costs for the thermal treatment application at Lipari Landfill (Lipari site) in New Jersey included $430 000 in capital cost and $5, 019, 292 in operation and maintenance costs - The unit cost for this application was $67/tonne based on treating 80 000 tonnes of soil. The land fill Lipari was used for disposal of a variety of household, chemical, and other industrial wastes (http://costperformance.org/profile.cfm?ID=137&CaseID=137).

239. Since the costs related to appropriate incineration and land filling are high and medium respectively, in developed countries, these settings are economically hard to manage in least developed countries. Based on these high costs, opportunities to substitute mercury-free alternatives may be the most preferable option.

240. When it comes to the benefits of incinerating or land filling, these are very large. Using the abatement cost e.g., $67/tonne) for land fill and $1047 /tonne for incineration (assuming 1 m^3 = 1 tonne), these costs are much lower than the damage avoided or the benefits reached if these management technologies are in use. Hence, the benefits of incinerating or land filling are very large compared to the total costs of these management technologies.

13. Prevention of mercury contamination from spreading

13.1. Overall assessment of costs and benefits

b. Small spills:

241. *Qualitative Cost Assessment: High costs compared to substitution costs of the used product*

242. *-Large spills:*

243. *Qualitative Cost Assessment: Very high costs*

244. *Qualitative Benefit Assessment: The damage is quite difficult to estimate depending on whether the spill takes place in a developed or a developing country.*

13.2. Mercury abatement efficiency and costs

245. When the quantities of mercury spills are large, measures are taken both in developed developing countries although the implementation of the measures may be different. In Europe and at the EU level the Commission Directive 93/112/EC of 10 December 1993 enable professional users to take the necessary measures relating to protection of health and safety at the workplace, and to protect the environment (http://www.reach.sgs.com/cts_directive_93_112_eec.pdf).

246. In the US, the Solid Waste Disposal Act of 1965, as amended, also known as the Resource Conservation and Recovery Act is the Federal Act that controls the management and disposal of solid and hazardous waste (http://www.epa.gov/osw/laws-reg.htm).

-Small spills

247. If the spilled quantities are small, in developed countries abatement measures are applied where the spill can be cleaned up by residents or workers following a set of relatively simple procedures. In the USA, for instance, many laboratories follow strict regulations on the use of mercury. There are well-documented procedures, especially in those accidents with broken glass and other cases when mercury is spilled. In all cases special removal kits are prescribed preventing any loss of mercury, which will evaporate afterwards. Moreover, special regulations and services exist to remove and store mercury at save places (http://www.knmi.nl/samenw/geoss/wmo/mercury/). In Canada, material from cleanup of mercury spills must be disposed of according to the provisions of the province's Environmental Management Act and the Hazardous Waste Regulation (http://www2.worksafebc.com/i/posters/2007/WS%2007_01.htm).

248. Generally in developing countries often small spills are not cleaned up. Mercury is still used in many instances such as small scale mining and disinfection

249. In the US the cost of mercury spills is a topic of interest because some hospitals gain support for mercury reduction programs by using spill cost avoidance as a justification for change (http://www.epa.gov/osw/laws-reg.htm). In general, the true costs of mercury spills are not well documented and tend to be anecdotal. However, the cost of substitution to products with no mercury may be lower. For example the clean- up costs of 1 broken sphygmomanometer is equivalent to $5000. For that cost, one could buy 30 or 40 non-mercury ones (http://www.epa.gov/osw/laws-reg.htm). Table 21 shows some examples giving insight on the potential cost of cleaning up mercury spills.

Table 21: Small spill of Mercury and its clean-up cost

Cost Estimate for Clean-up	**Reference & Description**
Small spill – over $1000 Large spill – around tens of thousands of dollars	http://www.middlecities.org/PDF/mercury_bulletin.pdf "Mercury Contamination Risk Control", Middle Cities Risk Management Trust, Okemos, MI "A typical thermometer contains ½ to 3 grams (.018 to .11 ounces) of mercury. A typical household mercury fever thermometer contains approximately 1 gram of mercury. A typical barometer contains 1 pound (454 grams) of mercury and poses a significant spill risk. The cost of cleaning up a spill will vary by the size of the spill and the degree of exposure to property and people. Small spill clean-ups usually cost over $1000 and large spills can go into the tens of thousands of US$. "
$10 000 for one broken barometer	http://www.pprc.org/pprc/pubs/topics/healthcare.html#mercury Northwest Guide to Pollution Prevention by the Healthcare Sector "A large barometer fell and broke in a 60 square foot office in a Medical Center located in the Puget Sound Region. The barometer was used to calibrate instruments used in treatment of patients. No one knew when the barometer fell and broke in the office. "The following are costs associated with the mitigation of the spilled mercury in this 60 square foot office area: Outside Vendor Cleanup Company – Time, Materials and Labor: $4000 Replacement of Mercury Spill Vacuum: $3200 Medical Follow up (Blood Testing) For Hospital Staff: $260 Mercury Disposal Costs: (Will Vary Per Vendor Used): $1600 Labor Hours Cost for Hospital Personnel Involved Est.: $1000 Total Costs for Spill Mitigation: $10060

Source: Adapted from http://www.sustainablehospitals.org/PDF/IP_spills_cost.pdf

-Large spills

250. Larger spills or spills in which the contamination has spread are often more expensive and difficult, as these spills involve more sophisticated methods of collection, decontamination, and disposal (http://www.epa.gov/osw/laws-reg.htm). For instance, in June 2000, a Newmont contractor carrying containers of mercury spilled 330 pounds of the chemical over 25 miles of roads and towns in Peru. The mercury was picked up by locals who thought it was valuable. Some of them boiled it on kitchen stoves looking for gold. The spill affected 1 100 people and required a massive, multimillion-dollar cleanup effort by Newmont that included digging up streets and the floors of homes. A later World Bank investigation found that Newmont had stopped using an Environmental Protection Agency-approved container for the mercury; that the mercury had been loaded incorrectly on an open truck; and that company officials initially misrepresented the size and seriousness of the spill, hampering emergency response efforts (http://www.theminingnews.org/news.cfm?newsID=191).

251. Hence, developing countries may have regulations relating to large spills but they are often not respected.

252. When it comes to large spilled quantities, the damage costs are difficult to estimate. In the case of Newmont, the mining firm offered up to around $5900 to more

than 700 local residents, but over 1 100 others are still engaged in a legal battle (http://en.wikinews.org/wiki/Peruvians_sue_Newmont_Mining_Company_over_mercury_poisoning

14. To address mercury containing waste and remediation of contaminated sites - Control and remediation of contaminated sites

14.1. Overall assessment of costs and benefits

253. *Qualitative Cost Assessment: many techniques can be used for cleaning up contaminated sites and the costs dependent on the used method.*

254. *Qualitative Benefit Assessment: Compared to cleaning up costs, the benefits may be very large*

14.2. Mercury abatement efficiency and costs

255. Given the unique behaviour of mercury, several techniques exist or are currently being developed for remediation of contaminated sites. The mercury species present in a given environment depend on the initial released form, the thermodynamic stability of this compound and the transformation rate of the released form to a more stable one (Baeyens et al, 1979). These issues must be well understood to design and evaluate effective and appropriate remedial solutions in areas contaminated by mercury (Hinton et al 2001). Any measure employed must consider the risk to ecological or human health and be accepted by regulators.

256. Below are some techniques including a qualitative description of their costs (adapted from: Minamata).

a. -Excavation and ex-situ treatment of mercury-contaminated soils is the most frequently employed practice for mercury recovery. Although excavation can be complicated if it extends below the water table or costly if the contamination is distributed over a large area, it is essentially a well-understood practice.

b. -Thermal Treatment: As the volatility of mercury and its compounds increase with temperature, thermal heating of excavated soil is a potentially effective means for mercury recovery from contaminated soils.

c. -Hydrometallurgical Treatments: Chemical extraction of mercury from excavated soils can be induced through four primaries mechanisms: desorption of adsorbed species; oxidation of metallic mercury; use of strong complexing agents; and through dissolution of precipitated mercury. Efficiency of any mechanism employed may decrease over time due to re-complexation and re-adsorption and removal of the most soluble compounds at early time.

d. -In-Situ recovery: Methods for in-situ recovery of mercury are far less established than ex-situ techniques. As well, due to subsurface heterogeneity, more uncertainly generally exists concerning the effectiveness of in-situ processes, and clean-up times tend to be longer than ex-situ treatments. Despite these factors, many in-situ technologies are very promising and – mainly due to the fact that contaminated soil and groundwater remain in the subsurface – may become more cost-effective and practical than excavation and treatment methods for many mercury-contaminated sites.

e. -Soil Vapour Extraction coupled with Soil Heating: Soil Vapour Extraction uses a vacuum to force air through the unsaturated zone. Currently, soil heating can be costly over expansive areas and difficult to homogeneously heat a soil volume.

f. In-situ Leaching and Extraction: Used in conjunction with Pump-and-Treat systems, In-situ leaching and extraction involves the injection of chemicals to enhance mercury solubility in groundwater, thereby reducing clean-up time and improving recovery rates from groundwater. Pump-and-treat is a frequently practiced, cost-effective remedial alternative employed either for removal contaminants from the subsurface and/or hydraulic containment of a contaminant plume.

g. -Electro-Kinetic Separation: This process involves the generation of an electric field through application of a low-voltage direct current in a soil matrix. Heavy metals, such as mercury, migrate towards electrodes placed in the soil where they accumulate and can subsequently be removed at a lower cost than excavating the entire impacted area.

h. -Interceptor Systems: Interceptor Systems, such as trenches and drains, are extremely simple and effective at recovering mercury as "free product" (essentially as metallic mercury); however, this treatment is limited by topography and stratigraphy and does not address mercury held in residual saturation.

i. Phyto-remediation: Phyto-remediation is a promising albeit unproven technology, wherein plants assimilate and concentrate metals from soils. This technique holds much promise for the cost effect remediation of shallow soils over a fairly widespread area, but issues such as limited access to vegetation by wildlife and time required for clean-up must be addressed.

257. For the sake of illustrating clean up costs, an example from Sweden may give some insight on the magnitude of these costs. EKA was a chlor-alkali firm which closed in 1928. The total costs to decontaminate the area where the industry was located are estimated to $28 million in 2008. About 90% of the estimated existing 16 tonnes of mercury will be removed leading to a cost of around $1 944 /kg Mercury. An extra benefit of this measure is a removal of around 850 g dioxin (http://www.nwt.se/ArticlePages/200707/09/20070709211004_437/20070709211004_437.dbp.asp).

258. Comparing the clean-up cost estimated in the Swedish case with Mercury damage related to ingestion of fish i.e. $12 500/kg Mercury, the benefits are much higher than the costs.

15. To increase knowledge through awareness raising and scientific information exchange - Increase of knowledge and capacity on mercury among states

15.1. Overall assessment of costs and benefits

259. *Qualitative Cost Assessment: Small to large*

260. *Cost Categories: Research, information sharing*

261. *Qualitative Benefit Assessment: Large.*

15.2. Increased knowledge on environmental assessment and options to reduce mercury pollution on global scale

262. Mercury pollution has been widely recognized as a global problem requiring global action.

263. One of the important issues in negotitating the global legally binding agreement on mercury is the understanding of the global mercury problem and its potential solutions by policy makers in individual countries and their political will to agree on reduction of mercury emissions and exposures. Increased knowledge on various options for such reduction is of primary importance towards obtaining such agreement. Therefore, there is considerable benefit to further increase knowledge of mercury contamination, specifically in the areas of inventories, human and environmental exposure, environmental monitoring, and socio-economic impacts.

264. International programs and conventions play a very important role in building capacity among various countries with regard to their knowledge on sources, environmental transport, effects and emission reduction options for mercury. The UNEP Toolkit for identification and quantification of mercury releases provides guidance on how to estimate emissions from various a range of sources national sources. Accurate and complete data on emissions is a prerequisite for any further assessment of fate and effects of contaminants, as well as for assessing their future changes. A number of countries used this Toolkit when calculating their national emissions for submission to UNEP (UNEP, 2008).

265. The most comprehensive international agreement regulating mercury to date is the 1998 Aarhus Protocol on Heavy Metals to the UN ECE Convention on Long-range Transboundary Air Pollution (LRTAP) (www.unece.org), This convention covers the European countries, the United States and Canada. The member countries report their emissions to the European Monitoring and Evaluation Programme (EMEP) (www.emep.int). The Aarhus Protocol establishes the emission reduction limits for mercury and other heavy metals and suggests best available techniques for limiting emissions from various sources. An important tool for improving the capacity on development of emission inventories and their future scenarios for the LRTAP countries, as well as other countries is the Joint EMEP/ CORINAIR Atmospheric Emission Inventory Guidebook

266. (http://reports.eea.eu.int/EMEPCORINAIR3/en/) (UN ECE, 2000).

267. The Arctic Council with its 8 member countries and 6 permanent participants representing Arctic indigenous groups is another setting providing the opportunity for capacity building and increasing knowledge on sources and impacts of mercury as a global pollutant. The Arctic Monitoring and Assessment Programme (AMAP) has been involved in development of global emission inventories for mercury (e.g. UNEP, 2008), monitoring the mercury levels in various environmental ecosystems in the Arctic and assessing environmental and human health impacts of this contaminant (e.g. AMAP, 2002)

15.3. Increased knowledge on environmental assessment and options to reduce mercury pollution on regional and national scale

268. Policy makers in Europe have taken the advantage of improved information on emissions. Following the preparation of a Position Paper on Ambient Air Pollution by Mercury (http://europa.eu.int/comm/environment/air/background.htm#mercury see also EU 2001), the EU adopted the European Mercury Strategy (http://europa.eu.int/comm/environment/chemicals/mercury), the EU Community Strategy Concerning Mercury. The development of this strategy has been accompanied by a number of research projects supported by the European Commission to obtain more knowledge on mercury and to develop tools that can be used by the EU member states and other countries to assess emissions, fate, and impacts of mercury pollution and to propose policies on how to reduce these emissions and impacts. These projects include: MAMCS (Mediterranean Atmospheric Mercury Cycle System: www.eloisegroup.org), MOE (Mercury Over Europe: www.eloisegroup.org), MERCYMS (An Integrated Approach to Assess the Mercury Cycle into the Mediterranean Basin: www.iia-cnr.unical.it/MERCYMS/project.htm), and ESPREME (Estimation of Willingness-to-pay to Reduce Risks of Exposure to Heavy Metals and Cost-benefit Analysis for Reducing Heavy Metals Occurrence in Europe: http://espreme.ier.uni-stuttgart.de). A large data base has been developed and used in various countries on emission control technologies that can be used to reduce emissions from various sources with information on the efficiency of these technologies and their investment and operational costs.

269. The overall objective of the EU DROPS project (http://drops.nilu.no) was to provide a full-chain analysis related to impact of health protection measures related to priority pollutants, including mercury in order to support the development of cost effective policy measures against pollution related diseases and their wider impacts (Pacyna, 2008). The main achievement of the project is the development and application of methodology for the assessment of costs and benefits from the implementation of measures for the reduction of human exposure to selected contaminants. This methodology consists of models, analytical procedures, and databases. The models and databases developed within the EU projects can be used in countries worldwide after certain adjustments to specific conditions that may be in place when using the European data outside the region.

270. The body of mercury information developed by the United States is described or referenced in the U.S. EPA’s Roadmap for Mercury of July 2006 (www.epa.gov/mercury). International cooperation and capacity building was fond in the Roadmap as an important tool to help further mercury reduction efforts. For example, the United States participated in a capacity building program to help the government of Burkina Faso develop a more accurate and comprehensive mercury inventory. This work helped to inform local authorities on environmental concerns, setting the stage for the development of and regulations for mercury control.

271. The South African Mercury Assessment (SAMA) program has been organized in South Africa to improve the knowledge on sources, behaviour and impacts of mercury in the country (Leaner et al., 2008). Another initiative to improve our knowledge on these issues is the South African – Norwegian project on mercury in South Africa (MERSA). Both initiatives can provide a possibility for capacity building on mercury pollution in the whole continent of Africa with benefits to other African countries.

15.4. Increased knowledge as a factor to the development of policy options

272. Major benefits of an increased knowledge for the development of policy options to reduce pollution were reviewed by Swain et al. (2007). The following policy options were reviewed: 1) policy options to reduce releases of mercury to the environment and 2) policies to limit exposures to mercury through risk communication. Releases of mercury to the environment can be reduced by policies related

to the supply or demand of mercury, implementation of technological controls for reduction of industrial emissions or discharges from waste disposal, or the reduction of quantities of produced goods that result in such releases. In general, policy options used routinely to reduce pollutant emissions from industrial processes include technology requirements, emission performance standards, emission taxes, and cap-and-trade (CAP) approaches. Other policy options such as subsidies and restrictions on the sale and disposal of mercury (and mercury-containing items) could influence mercury releases from small-scale practices such as artisanal gold mining. Application of any of these alternative policies to mercury reduction will have benefits and costs. An economic approach to evaluating different policy options is to balance, at the margin, the benefits and costs of any policy option. Such policies are deemed economically efficient. The knowledge of policy options, their efficiency in mercury reduction and cost of implementation, as well as environmental, and human health benefits is needed for policy making at a national and regional level in order to introduce ecosystem based management of environmental resources in a given country.

273. In the case of mercury, economic analysis is complicated by the need to track benefits and costs at various geographic scales, from local to global. While the costs associated with the implementation of new processes or control technologies can be estimated in a relatively straightforward manner, the assessment of benefits is complicated by the scientific uncertainties reported in the environmental literature [i.e., the linkages between reducing environmental mercury releases and lower levels of mercury in the atmosphere and in fish (Lindberg et al., 2007; Munthe et al., 2007)] and health science literature [i.e., linkages between reduced levels in the environment, reduced exposures, and health improvement (Munthe et al., 2007). Ideally, economic analyses highlight these uncertainties as well as those introduced in the benefit–cost component of the analysis, and researchers will conduct additional analyses to assess the sensitivity of the results to the assumptions associated with the uncertainties (US EPA, 2000).

274. In addition to reducing mercury releases, human mercury exposures can also be reduced through risk communication policies, including fish consumption advisories, improved communication of the occupational risks associated with mercury releases during artisanal gold mining, and product labelling. Consumption advisories and the risk communication challenges associated with small-scale gold mining are often in focus. However, the practical implications of advisories on fish consumption have seldom been documented, and most likely vary a great deal depending on the nature of the advice, how it is communicated, and the alternatives available to the community.

275. Information digests for policy making with regard to the costs and benefits of reducing mercury emissions and exposure can be the way for communication of scientific knowledge to the policy makers at state, regional, and local levels. The development of information digests can be coordinated by the UNEP Global Mercury Partnership. The digests should include the guidance on how to prepare economic analysis (such as the U.S. EPA, 2000) and databases with information on efficiency and costs of possible environmental protection measures (such as the EU ESPREME project database http://espreme.ier.uni-stuttgart.de) the EU DROPS project database (http://drops.nilu.no).

276. Mercury Information Clearinghouse is another example of how the latest information on mercury policy, measurement, baseline levels and emissions, and control could be communicated to policy makers, as well as general public with mercury users and consumers. An example of such an information channel is the Mercury Information Clearinghouse on Advanced and Developmental Mercury Control Technologies available from the national technical Information Service at the U.S. department of Commerce (U.S. DoC, 2004).

277. Training workshops can be organized in different parts of the world with regard to the use of existing methods and databases on the assessment of benefits and costs related to the reduction of mercury pollution worldwide. Such workshops can be organized under auspicious of the UNEP Global Mercury Partnership.

16. To increase knowledge through awareness-raising and scientific information exchange - Increase of knowledge and capacity among individual mercury users and consumers

16.1. Overall assessment of costs and benefits

278. *Qualitative Cost Assessment: Small.*

279. *Cost Category: Consumer education.*

280. *Qualitative Benefit Assessment: Large.*

16.2. Capacity building as an instrument for pollution mitigation

281. Increased information knowledge and capacity building among individual mercury users and consumers may be seen as a policy instrument to reduce the emissions of mercury and thereby the environmental and health impacts of this pollutant. Capacity building, provision of information and increasing co-operation are cost effective instruments to mitigate pollution.

282. Capacity building can be defined as "*People helping people to build skills to change their own future. Skills can be built a number of levels, including at the level of the individual, organization, community or system"*. Furthermore, a World Bank summary of participatory processes refers to capacity building as the improved ability to make decisions about a project and transfer information between groups. The focus is on building people's capacity to participate in decision-making about a certain subject, as opposed to identifying capacities in a community and strengthening these elements.

283. The information instruments: When it comes to informational instruments a distinction is usually made between information strategies for production and information strategies for consumption. Examples of information based strategies that may be introduced by government towards a cleaner production include (UNEP (2001)):

promoting the adoption of targeted, high-profile demonstration projects, to demonstrate the techniques and cost-saving opportunities associated with cleaner production.

encouraging educational institutions to incorporate preventive environmental management within their curricula, particularly within engineering and business courses

issuing high profile awards for enterprises that have effectively implemented cleaner production.

284. Since it is often difficult or in some cases impossible for consumers to trace the original causes of environmental problems, it is vital that the authorities also use information instruments to improve consumers' understanding and awareness of these issues. Extensive research and monitoring work must be supported and published and public awareness of environmental issues should be increased through education and special training. Other informative measures such as environmental labelling schemes attempt to control consumption patterns by encouraging consumers to use products and services that are less harmful to the environment (Finland Env. Ad. 2006).

285. Voluntary and co-operative regulatory instruments that do not involve the public directly include energy auditing schemes, promotion of energy savings, promotion of technologies, golden carrot programmes (e.g. subsidising development and implementation of energy saving products and technologies) and other 'soft' policy instruments. These programmes can be understood as subsidising development or supply of preferred technologies and subsidies for provision of certain types of costly information to firms.

286. The benefits of capacity building may be summarized in the following:

a. -increase recycling

b. -increased use of substitutes

c. -clean up of spills e.g., remediation of contaminated sites

d. -increase of storage of excess mercury

16.3. Communication of risk of mercury pollution to mercury users and consumers

287. Proper communication of the risk of mercury pollution to mercury users and consumers is of vital importance with regard to reducing environmental and human health impacts. The issue of risk communication is related to the non-technological measures to limit emissions and exposure to mercury.

288. The most known non-technological methods of mercury emission reduction include energy conservation and pollution prevention solutions. Energy conservation means using less energy to achieve the same level of energy service, including heat, light, sound, shaft power, and mobility. Decreasing energy production and use will result in the decrease of mercury emissions and provide additional benefits of reducing emissions of sulfur dioxide and other pollutants. A system of credits or vouchers could be developed and presented to the utilities for mercury reduction goals. Demand-side management (DSM) programs should be identified. DSM refers to actions undertaken by, for example, electric utility to modify customer demand patterns. DSM programs may consist of information dissemination, technologies, or financial incentives.

289. A few solutions of pollution prevention can be presented for mercury, including:

a. materials separation,
b. product content bans,
c. input taxes on the use of mercury in products, and
d. labeling of products.

290. Material separation deals mostly with the separation of mercury containing materials from the waste streams of MWCs and MWIs. A very small portion of wastes (perhaps less than 1 %) containing very high content of mercury from batteries, fluorescent lights, thermostats and other electrical items needs to be separated from the rest of the wastes, such as paper, plastic or dirt, containing very low concentrations of the element. Several communities in many countries all over the globe have already implemented household battery separation programs in an effort to reduce mercury in wastes to be incinerated.

291. Labelling mercury-containing products would help consumers to select the ones which are mercury-free. This is particularly important for switches and devices that most consumers would not expect to contain mercury.

292. Consumer education and awareness is also an important aspect of dealing with the public health threats posed by mercury. Considerable benefit has been found in Europe and the United States in consumer awareness programs as awareness provides a critical tool for preventing exposures. Experiences with responding to and cleaning up local mercury spills and other unusual mercury hazards demonstrates that quick communication and effective response can make all the difference between mercury poisoning and a quick, easy clean-up effort. Experience also shows that making sure that contaminated areas are quickly identified and that local residents are aware of how to recognize and report environmental hazards can greatly help to prevent avoidable exposure. Well-established notification procedures go hand in hand with effective clean-up and rehabilitation policies and processes in helping to safeguard the public.

293. Elemental mercury is put to magico-religious uses, most problematically the sprinkling of mercury on floors of homes in Caribbean and Latino communities. Indoor mercury spills are persistent and release toxic levels of mercury vapour over long periods of time (e.g. Wendroff, 2005). It is claimed that ritualistic mercury contamination should be taken seriously by both the public health and the environmental health communities. Risk communication is an important issue in the matter.

294. Consumer advisories with regard to the risk to mercury pollution are also very important elements of capacity building of users and consumers. Fish consumption advisories were mentioned in the previous chapter. Various reference doses with regard to safe level of methyl-mercury content in fish were proposed by various organizations, such as Food and Agriculture Organization (FAO), the European Commission, Health Canada, the U.S. Food and Drug Administration (FDA), the US EPA, ranging from 0.1 to 0.4 of methyl-mercury per kg of body weight per day. It is very important that consumers are properly advised on the safe level of methyl-mercury in fish. However, it should be

remembered that eating fish provides high nutritional value such as vitamins A, F, and C, protein, omega-3 fatty acids, mono-lipids, iron and zinc.

295. Another example of a risk communication could be advisories to small scale gold miners and their families (Swain et al., 2007). In the case of small-scale gold mining using mercury amalgamation, the primary toxicological issue is the inhalation of mercury converted to the gas phase during the heating of the amalgam. Heating often takes place inside or near the home. Artisanal workers and their families can be exposed to harmful levels of mercury vapor. Risk communication in the form of advice to avoid the mercury amalgamation technique or to reduce exposure during its use must take into account the limited options available to the gold miners and the widespread poverty and hardship associated with this occupation. Field researchers (e.g., Vega and Hinton, 2002; Spiegel et al., 2006) emphasize that effective risk communication strategies need to be intertwined with strategies targeting improved profitability through better gold recovery methods or reduced losses of mercury, thus reducing the artisanal miner's production costs. Within each country, the industry is geographically scattered, so the logistical aspects of risk communication are a major challenge. Thus, to be effective, in each region, risk communication strategies may involve training a cadre of small-scale gold miners who can demonstrate and discuss the advantages of improved practices to their fellow miners (Spiegel et al., 2006).

296. Industries using mercury should also take responsibility for informing the public on human health risks related to their products. For example, the Computer TakeBack Campaign aims to protect the health and well-being of electronics users, workers, and the communities where electronics are produced and discarded by requiring consumer electronics manufacturers and brand owner to take full responsibility for the life cycle of their products (www.computertakeback.com)

17. Concluding remarks

297. During the recent decade major progress has been made in the assessment of anthropogenic sources of mercury and development of emission inventories on national, continental and even global scale, including development of scenarios addressing mercury emissions until 2020 (UNEP,2008). Key to the consideration of costs and benefits are:

a. what are the abatement costs for mercury emission reductions using various measures in different emission source categories?, and
b. what are the environmental and societal benefits of mercury emission reductions?

298. In an attempt to deal with these questions, a qualitative assessment of the potential costs and benefits associated with mercury reductions within major emission source categories has been attempted in this report. This assessment started with the information on socio-economic consequences of mercury use and pollution, integrated and synthesized within the paper published by a group of authors including Swain (the lead author), Jakus, Rice, Lupi, Maxson, Pacyna, Penn, Spiegel and Veiga in the Ambio journal in 2007 (Swain et al., 2007).

299. A number of technical and non-technical measures are available for reducing the mercury emissions from: anthropogenic sources where mercury is a by-product (e.g. power plants, smelters, cement kilns, other industrial plants), waste disposal and other various uses. Measures differ with regard to emission control efficiency, costs, and environmental benefits obtained through their implementation. Very often mercury emissions are substantially reduced by equipment employed to reduce emissions of other pollutants. The best example is the reduction of mercury emissions by the desulfurization installations. The same applies to de-NOx installations, and control devices reducing emissions of fine particles. It can be concluded that technical measures for mercury emission reduction are available within the major emission sources categories, such as combustion of coal to produce electricity and heat, manufacturing of non-ferrous metals, iron and steel production, cement industry and waste incineration. These measures vary with respect to the emission control efficiency and cost. Most measures could reduce mercury emissions from the above mentioned sources by up to 90 % without employing any "add on" equipment, such as adding absorbents specific for mercury.

300. Since the sources of waste containing mercury differ and the emissions from these sources are local and/or region specific, the costs to reduce the generation of wastes differ depending on the infrastructure available within the country. Preliminary Qualitative Cost Assessment reveals that these costs are variable depending on the management technique, such as incineration and land filling. Whilst the introduction of various emission control measures may give results in the developed world, the outcome of this strategy may not be very positive in the developing world where there is often no

differentiation between municipal, hazardous and medical waste in terms of applied techniques or achievable emission limits. Therefore, emphasis in developing countries should be put on developing adequate policy instruments to mitigate mercury releases.

301. Efficient, non-technological measures and pre-treatment methods are also available for the reduction of mercury releases from various uses of products containing mercury. These measures include bans on use and substitution of products containing mercury, and cleaning of raw materials before their use (e.g. coal cleaning). These measures also include energy conservation options, such as energy taxes, consumer information, energy management and improvement of efficiency of energy production through a co-generation of electricity and heat in coal-fired power plants. These measures also include prevention options, such as mercury containing wastes and material separation, labeling of mercury containing products, and input taxes on the use of mercury in products.

302. Capacity building through improvement of knowledge on mercury pollution impacts, emission reduction options, and their costs among authorities responsible for environmental protection in various countries and among individual mercury users and consumers is also a very important issue at present, as explained in the reported work.

303. The costs of mercury spills are not well documented and tend to be anecdotal. In the developed world costs to clean up small spills are very high compared to both the benefits of cleaning up as well as the costs of substituting the products with potential spill. For large spills the damage costs as well as the abatement costs are quite difficult to estimate depending on where the spill occurs.

304. Information is becoming available from the literature on benefits to the environment and society from implementation of various emission control measures for mercury. Environmental and human health consequences associated with mercury pollution have been studied for several decades, starting immediately after the Minamata disease was reported in 1956. The Swedish Medical Board issued bans for sale of fish from certain rivers and lakes due to high concentrations of methyl-mercury in 1967. The US Sport Fishing Institute suggested in 1969 that mercury may be a larger threat than DDT (cited in Eckley Selin, 2005). It became clear that ingestion of methyl-mercury with contaminated food is more dangerous than inhalation of inorganic mercury. Contaminated fish became the main factor in this context. However, there have been several reservations on how to relate the emission of inorganic mercury from various anthropogenic sources to the concentrations of methyl-mercury in fish and then ingestion of methyl-mercury. These reservations have not helped in the development of dose-response functions for mercury, which have only recently been developed.

305. The development of dose-response functions is a very important step in estimating environmental and human health benefits from reducing the mercury exposure and emissions in the first place. The societal cost-benefit analysis has not been a subject of the reported work. The results of the reported work are meant to contribute to such analysis to describe the environmental and socio-economic impacts of mercury emission reductions at local, regional (e.g. continental) and global scale. However, the data reported here were used in another study to a preliminary estimate of societal costs and benefits of mercury reduction on global in the case that there will be a status-quo with mercury pollution in the future (Pacyna et al., 2008). This study concluded that the overall environmental and human health benefits from the reduction of mercury emissions from anthropogenic sources are considerable. The final conclusion of this study was that there are good reasons to invest in reducing mercury emissions and exposure in the future primarily for the sake of improvement of human health and more generally human welfare, also from economic point of view. The study reported here adds that there are measures for mercury emission reduction for which this investment can be done.

306. The development of dose-response functions has been also a very important factor in the assessment to what extend the emissions of mercury should be reduced, in particular to address weither mercury use should be phased-out or reduced. In considering phasing out mercury use, are adequate substitutes available. If the aim is to reduce Mercury emissions, are the measures considered efficient enough. And finally, can we afford from economical point of view to implement measures, necessary for mercury emission reductions? The reported work has been challenged to address these questions, however, more research is needed to provide more detailed answers. The matter is further complicated by the fact that mercury is a global contaminant with emissions in one region to be deposited in another region. It has been recognized that the current efforts to reduce risks from mercury are not sufficient to address the global challenges posed by mercury and governments are commencing the negotiation of a global legally binding instrument on mercury. The consideration of the costs and benefits of taking (or not taking) actions will provide input into that discussion.

307. Information on costs and benefits of mercury reductions within the provisions discussed in this report is available in Table 22.

Table 22: Costs and benefits of Mercury emission reduction for various reduction options

Issues within the comprehensive and suitable approach to mercury	Reduction option	Costs	Benefits
(b) To reduce the supply of mercury and enhance the capacity for its environmentally sound storage	Reduction of supply from mining and extraction	Small → Medium	Large
	Reduction of supply from decommissioned cells and stockpiles	Small → Medium	Large
(c) To reduce the demand for mercury in products and processes	Reduction of Mercury consumption in VCM and chlor-alkali production	Small → Large	Medium → Large
	Reduction of Mercury use in products	Small	Large
	Reduction from dental practice	Small → Large	Medium
(d)To reduce international trade in mercury	Reduction of Mercury trade emissions	Small	Large
(e) To reduce atmospheric emissions of mercury	Reduction from coal usage	Medium →Large	Large
	Artisanal and small – scale gold mining	Small → Large	Small → Large
	Reduction from industrial processes	Medium → Large	Medium → Large
(f) To address mercury containing waste and remediation of contaminated sites	Reduction of waste generation	Small → Large	Large
	Promotion of Mercury waste collection and treatment	Small → Medium	Large
	Reduction from waste disposal	Medium → Large	Large
	Prevention of contamination from spreading	Large	Medium → Large
	Control and remediation of contaminated sites	Small → Medium	Large
(g) To increase knowledge through awareness raising and scientific information exchange	Increase of knowledge among states	Small → Large	Large
	Increase of knowledge among users and consumers	Small	Large

308. It can be seen from Table 22 that costs and benefits vary significantly within various mercury reduction options. Measures with the application of technology, such as implementation of installations to remove mercury from the flue gases in electric power plants, waste incinerators, and smelters are rather expensive (medium to large costs) compared to non-technological measures, such as prevention activity, capacity building, and promotion of mercury-containing waste separation (small to medium costs). Both groups of measures would result in large benefits. This indicates that the technological and non-technological solutions for mercury emission and exposure reductions can be carried out in parallel. More emphasis on technological measures can be put in the developed countries, while the process of emission and exposure reduction in the developing countries may start with non-technological solutions. Technological solutions may be introduced in these countries gradually as a follow-up process after non-technological solutions are in place.

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