UNITED NATIONS
ENVIRONMENT PROGRAMME
CHEMICALS

GLOBAL MERCURY ASSESSMENT

A drop of mercury

IOMC INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS
A cooperative agreement among UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD

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Key findings of the report

WHY SHOULD WE BE CONCERNED AND CAN INTERVENTION RESULT IN CHANGE?

Mercury is Present throughout the Environment

1. Environmental mercury levels have increased considerably since the on-set of the industrial age. Mercury is now present in various environmental media and food (especially fish) all over the globe at levels that adversely affect humans and wildlife. Widespread exposures are occurring due to human-generated sources, and past practices have left a legacy of mercury in landfills, mine tailings, contaminated industrial sites, soils and sediments. Even regions with no significant mercury releases, such as the Arctic, are adversely affected due to the transcontinental and global transport of mercury.

Mercury is Persistent and Cycles Globally

2. The most significant releases of mercury pollution are emissions to air, but mercury is also released from various sources directly to water and land. Once released, mercury persists in the environment where it circulates between air, water, sediments, soil and biota in various forms. Current emissions add to the global pool– mercury that is continuously mobilised, deposited on land and water, and re-mobilised.

3. The form of mercury released varies depending on source type and other factors. The majority of air emissions are in the form of gaseous elemental mercury, which is transported globally to regions far from the emissions source. The remaining emissions are in the form of gaseous inorganic ionic mercury forms (such as mercuric chloride) or bound to emitted particles. These forms have a shorter atmospheric lifetime and will deposit to land or waterbodies within roughly 100 to 1000 kilometres of their source. Elemental mercury in the atmosphere can undergo transformation into ionic mercury, providing a significant pathway for deposition of emitted elemental mercury.

4. Once deposited, the mercury form can change (primarily by microbial metabolism) to methylmercury, which has the capacity to collect in organisms (bioaccumulate) and to concentrate up food chains (biomagnify), especially in the aquatic food chain (fish and marine mammals). Methylmercury is therefore the form of greatest concern. Nearly all of the mercury in fish is methylmercury.

Mercury Exposure Has Serious Effects

5. Mercury has caused a variety of documented, significant adverse impacts on human health and the environment throughout the world. Mercury and its compounds are highly toxic, especially to the developing nervous system. The toxicity to humans and other organisms depends on the chemical form, the amount, the pathway of exposure and the vulnerability of the person exposed. Human exposure to mercury can result from a variety of pathways, including, but not limited to, consumption of fish, occupational and household uses, dental amalgams and mercury-containing vaccines.

6. Methylmercury is adversely affecting both humans and wildlife. This compound readily passes the placental barrier and the blood-brain barrier, and is a neurotoxicant, which may in particular cause adverse effects on the developing brain. Studies have shown that methylmercury in pregnant women's diets can have subtle, persistent adverse effects on children's development as observed at about the start of school age. Moreover, some studies suggest small increases in methylmercury exposure may cause adverse effects on the cardiovascular system. Many people (and wildlife) are currently exposed at levels that pose risks of these, and possibly other adverse effects.

7. Some populations are especially susceptible to mercury exposure, most notably the fetus, the newborn, and young children because of the sensitivity of the developing nervous system. Thus, parents,

pregnant women, and women who might become pregnant, should be particularly aware of the potential harm of methylmercury. Moderate consumption of fish (with low mercury levels) is not likely to result in exposures of concern. However, indigenous populations and others who consume higher amounts of contaminated fish or marine mammals, as well as workers who are exposed to mercury, such as in small-scale gold and silver mining, may be highly exposed to mercury and are therefore at risk.

8. Besides their importance to many native cultures, fish are an extremely valuable component of the human diet in many parts of the world, providing nutrients that are often not available in alternative food sources. Mercury is a major threat to this food supply. Likewise, contaminated fish can bring serious economic problems to communities and regions dependent on fisheries for their economic survival.

9. There are also particularly vulnerable ecosystems and wildlife populations. These include top predators in aquatic food webs (such as fish-eating birds and mammals), Arctic ecosystems, wetlands, tropical ecosystems and soil microbial communities.

Intervention Can be Successful

10. Mercury pollution has significant impacts at local, national, regional and global levels. These impacts can be addressed through a range of actions at each of these levels, targeting reductions in uses, releases and exposures. Numerous actions implemented in Europe, North America and elsewhere have successfully reduced uses and releases of mercury. However, inventories are still incomplete in these regions, and some releases are still significant. The extent of decreases in environmental levels and ecosystem improvements in response to decreased releases of mercury will vary considerably depending on local ecosystem characteristics and other factors, and in some cases may take several decades. However, an evaluation of mercury levels in Swedish lakes indicates that, by reducing releases, environmental levels of mercury, such as in freshwater fish, may be reduced significantly in specific locations within one to two decades.

WHY IS LOCAL/REGIONAL ACTION, BY ITSELF, NOT SUFFICIENT?

Global Cycling of Mercury Increases the Problem

11. As described above, the origins of atmospheric mercury deposition are local and regional as well as hemispherical or global. Besides local sources of mercury releases (such as waste incineration and coal combustion facilities), the general global background concentrations (global pool) contribute significantly to the mercury burden at most locations. Similarly, virtually any local source contributes to the global pool. Also, rivers and ocean currents are media for long-range mercury transport.

12. In some nations, local and regional mercury depositions have gradually increased contamination levels to the point that countermeasures have been enacted in recent decades to reduce emissions. However, due to long-range transport, even nations with minimal mercury releases, and other areas remote from industrial activity, may be adversely affected. For example, high mercury levels are observed in the Arctic, far from the sources of any significant releases.

Mercury Has an Impact on Global Fishing

13. Many fish species in international waters migrate to remote and diverse locations. Moreover, after harvest, commercial fish are commonly exported to various nations throughout the world, to locations far removed from place of origin. Therefore, mercury contamination of lakes, rivers, and especially oceans is truly a global issue, affecting fishing industries and fish consumers around the world.

Mercury May Be More Problematic to Less-Developed Regions

14. As awareness of mercury's adverse impacts has increased, the uses of mercury have been reduced significantly in many industrialised countries. Alternatives are commercially and competitively available for most uses. However, these reductions in use have had the effect of lowering demand relative to the supply of mercury, which has kept mercury prices low and encouraged ongoing (and in some cases, increased) use of mercury and outdated mercury technologies in less-developed regions or nations. As mer-

cury regulations and restrictions are less comprehensive or less well enforced in many less-developed regions, these trends have contributed to the concentration, in these areas, of a disproportionate burden of some of the health and environmental risks that accompany mercury.

Mercury is Subject to Significant International Use and Commerce

15. Despite improved awareness of risks, mercury continues to be used in a variety of products and processes all over the world. Elemental mercury metal is used in small-scale mining of gold and silver; chlor-alkali production; manometers for measurement and control; thermometers; electrical switches; fluorescent lamps; and dental amalgam fillings. Mercury compounds are used in batteries; biocides in the paper industry, pharmaceuticals; paints and on seed grain; and as laboratory reagents and industrial catalysts.

16. There is significant ongoing trade in mercury and mercury-containing products, some of which is illegal, uncontrolled and/or unregulated. The most significant global movement of mercury that remains poorly understood is the flow of mercury through international commerce. While overall quantities of mercury traded (and mined) have diminished in recent years, significant amounts are still transported. The unabated demand in many developing nations is a particular concern. Mercury available on the world market is supplied from a number of sources, including, among others:

- Mining of mercury (extracted from ores within the earth's crust) either as the main product or as a by-product of mining and refining other metals (gold, zinc) or minerals;
- Private and government stocks (mercury in chlor-alkali plants, government reserves);
- Recycled mercury recovered from spent products and industrial wastes.

17. Even under current regulations and restrictions, many of the uses and movements of mercury and mercury containing products are likely to eventually result in the release of mercury to the global environment. Meanwhile, large amounts of mercury that remain in mine tailings, landfills and sediments, as well as stockpiles, continue to present a threat of future release. Hence, actions to reduce, manage and address uses, stocks and trade may be useful at local, regional, national and international levels to prevent or minimize future releases.

HOW DOES MERCURY GET INTO HUMANS AND WILDLIFE?

18. Although local conditions may affect mercury exposure in certain populations, most people are primarily exposed to methylmercury through the diet (especially fish) and to elemental mercury vapours due to dental amalgams and occupational activities. The toxicity of methylmercury is described above. Elemental mercury vapour is also toxic to the nervous system and other organs. While methylmercury is of greatest concern for general populations, elevated exposures to elemental mercury are also of concern.

19. Elevated methylmercury levels have been measured in numerous freshwater and marine fish species throughout the world. The highest levels are found in large predatory fish and fish-consuming mammals. Exposure studies from diverse geographic areas indicate that a significant portion of humans and wildlife throughout the world are exposed to methylmercury at levels of concern, primarily due to consumption of contaminated fish.

20. Depending on local mercury pollution load, substantial additional contributions to the intake of total mercury can occur through air and water. Also, personal use of skin lightening creams and soaps, mercury use for religious, cultural and ritualistic purposes, use in some traditional medicines and mercury in the home and working environment can result in substantial elevations of human exposure. Exposures also occur through the use of vaccines and some other pharmaceuticals containing mercury preservatives (such as Thimerosal/Thiomersal).

21. Elevated elemental mercury levels in the working environment have been reported in chlor-alkali plants, mercury mines, thermometer factories, refineries, dental clinics, and in mining and manufacturing of gold and silver extracted with mercury. The relative impacts from local pollution (such as former mining sites), occupational exposure and local traditions may vary considerably between nations and are known to be significant in some areas.

22. Numerous wildlife species that rely on fish as a large part of their diet can have elevated mercury levels that raise the risk of adverse effects. Animals with the highest mercury levels include otter, mink, raptors, osprey, and eagles, which are top predators in the aquatic food chain. For example, eggs of certain Canadian bird species have mercury levels that are a threat to reproduction. Moreover, mercury levels in Arctic ringed seals and beluga whales have increased by 2 to 4 times over the last 25 years in some areas of the Canadian Arctic and Greenland. In warmer waters, some predatory marine mammals are also at risk. In addition, recent evidence indicates that soils are adversely affected over large parts of Europe and potentially in many other locations. However, in some environments, even fairly heavy mercury loads have very little effect on organisms as either mercury is not efficiently bioaccumulated throughout the local food chain or the mercury is not easily methylated. In addition, the effects of watershed management practises in certain locations on methylmercury levels may be more significant than the effects of direct or diffuse mercury inputs.

WHAT ARE THE PRIMARY SOURCES OF MERCURY RELEASES?

23. The releases of mercury can be grouped in four categories:

- Natural sources - releases due to natural mobilisation of naturally occurring mercury from the Earth's crust, such as volcanic activity and weathering of rocks;
- Current anthropogenic (associated with human activity) releases from the mobilisation of mercury impurities in raw materials such as fossil fuels – particularly coal, and to a lesser extent gas and oil – and other extracted, treated and recycled minerals;
- Current anthropogenic releases resulting from mercury used intentionally in products and processes, due to releases during manufacturing, leaks, disposal or incineration of spent products or other releases;
- Re-mobilisation of historic anthropogenic mercury releases previously deposited in soils, sediments, water bodies, landfills and waste/tailings piles.

24. A large portion of the mercury present in the atmosphere today is the result of many years of anthropogenic emissions. The natural component of the total atmospheric burden is difficult to estimate, although available data suggest anthropogenic activities have increased levels of mercury in the atmosphere by roughly a factor of 3, average deposition rates by a factor of 1.5 to 3 and deposition near industrial areas by a factor of 2 to 10.

25. Highly contaminated industrial sites and abandoned mining operations continue to release mercury. Also, land, water and resource management activities such as forestry and agricultural practices and flooding can make mercury more bioavailable. Methylation and bioaccumulation are influenced by high levels of nutrients and organic matter in water bodies. In addition, frequent extreme weather events can contribute to release of mercury through flooding and soil erosion.

WHAT ARE THE ANTHROPOGENIC SOURCES?

26. With regard to anthropogenic releases, the relative importance of releases associated with intentional uses versus mobilisation of mercury impurities vary between nations and regions, particularly depending on: extent of substitution of intentional uses (products and processes); reliance on fossil fuels, particularly coal, for energy; extent of mining and mineral extraction industry; waste disposal practices; and state of implementation of pollution control technologies. In nations where there is mercury mining or use of mercury for small-scale gold or silver mining, these sources can be quite significant.

27. Some of the more important anthropogenic processes that mobilise mercury impurities include: coal-fired power and heat generation; cement production; and mining and other metallurgic activities involving the extraction and processing of mineral materials, such as production of iron and steel, zinc and gold. Some important sources of anthropogenic releases that occur from the intentional extraction and use of mercury include: mercury mining; small-scale gold and silver mining; chlor-alkali production; (breakage during) use of fluorescent lamps, auto headlamps, manometers, thermostats, thermometers, and

other instruments; dental amalgam fillings; manufacturing of products containing mercury; waste treatment and incineration of products containing mercury; landfills; and cremation.

HOW CAN RELEASES BE REDUCED?

28. Reducing or eliminating anthropogenic mercury releases will require controlling releases from mercury-contaminated raw materials and feedstocks as well as reducing or eliminating the use of mercury in products and processes. The specific methods for controlling these mercury releases vary widely, depending upon local circumstances, but fall generally under four groups:

- Reducing mercury mining and consumption of raw materials and products that generate releases;
- Substitution of products and processes containing or using mercury;
- Controlling mercury releases through end-of-pipe controls; and
- Mercury waste management.

29. The first two of these are "preventive" measures – preventing some uses or releases of mercury from occurring at all. The latter two are "control" measures, which reduce (or delay) some releases. Preventive measures for reducing consumption of raw materials and products that generate mercury releases are generally cost-effective, and among the most viable means of eliminating mercury releases. Also, substitution of products and processes without mercury is an important preventive action.

30. Controlling mercury releases through end-of-pipe techniques, such as exhaust gas filtering, may be especially appropriate to processes using raw materials with trace mercury contamination - fossil-fueled power plants, cement production, extraction and processing of primary raw materials such as zinc, gold and other metals, and processing of secondary raw materials such as steel scrap. Existing control technologies that reduce sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM) for coal-fired boilers and incinerators, while not widely used in many countries, also yield some level of mercury control. Technology for additional mercury control is under development and demonstration, but is not yet commercially deployed. In the long run, integrated multi-pollutant (SO_2, NO_x, PM, and mercury) control technologies may be a cost-effective approach. However, end-of-pipe control technologies, while mitigating the problem of atmospheric mercury pollution, still result in mercury wastes that are potential sources of future emissions and should be disposed of or reused in an environmentally acceptable manner.

31. Mercury waste management has become more complex as more mercury is collected from a variety of sources, including gas filtering products, sludges from the chlor-alkali industry, ashes, and mineral residues, as well as used fluorescent tubes, batteries and other products that are often not recycled. The cost of acceptable disposal of mercury waste in some countries is such that many producers now investigate whether alternative non-mercury products exist. Proper management of mercury wastes is important to reduce releases to the environment, including those that occur due to spills (such as broken thermometers) or releases that occur over time due to leakage from certain uses (such as auto switches and dental amalgams) or releases through waste incineration and cremation. A well thought-out combination of prevention and control measures is necessary to optimize reductions in mercury releases.

32. Many nations have implemented actions to limit and prevent uses, releases and exposures, such as:

- Actions and regulations that control mercury releases into the environment;
- Product control actions and regulations for mercury-containing products;
- Environmental quality standards, specifying a maximum acceptable mercury concentration for different media such as drinking water, surface waters, air, soil and foodstuffs such as fish;
- Other standards, actions and programmes, such as regulations on mercury exposures in the workplace, reporting requirements, fish consumption advisories and consumer safety measures.

33. Although legislation is a key component of most national initiatives, other efforts exist to reduce mercury use such as developing and introducing safer alternatives and cleaner technology, the use of subsidies and incentives to encourage substitution efforts, voluntary agreements with industry, and awareness raising.

34. Because of mercury's long-range cycling and persistence in the environment, a number of countries have already initiated measures at regional, sub-regional and international levels to identify common reduction goals and ensure coordinated implementation among countries.

WHAT WOULD IMPROVE OUR UNDERSTANDING AND INTERNATIONAL COORDINATION?

35. Despite data gaps, sufficient understanding has been developed of mercury (including knowledge of its fate and transport, health and environmental impacts, and the role of human activity), based on extensive research over half a century, that international actions to address the global mercury problem should not be delayed. Nonetheless, further research and other activities would be useful to improve our understanding and coordination in a number of areas, including:

- Inventories of national uses, consumption and environmental releases;
- Information on transport, transformation, cycling, and fate of mercury in various compartments;
- Assessment and monitoring of mercury levels in various media (such as air and air deposition) and biota (such as fish), and associated impacts on humans and wildlife, including impacts from cumulative exposures to different forms of mercury;
- Data and evaluation tools for human and ecological risk assessments;
- Additional measures to prevent and reduce releases from various sources;
- Collaboration among nations dealing with the spectrum of scientific and technical issues, including mercury waste management and remediation; and
- Information on the global commerce and trade of mercury and mercury-containing materials.

Summary of the report

CHAPTER 1 - Introduction

36. This report responds to the request of the Governing Council (GC) of the United Nations Environment Programme (UNEP), through GC decision 21/5, that UNEP undertake a global assessment of mercury and mercury compounds, in cooperation with other members of the Inter-Organization Programme for the Sound Management of Chemicals (IOMC), to be presented to the Governing Council at its 22nd session in 2003. The assessment would include contributions from Governments, intergovernmental and non-governmental organizations and the private sector, and cover a number of specific elements defined in the GC decision. These elements are covered as far as possible in the different chapters of the report.

37. As part of the implementation of GC decision 21/5, UNEP established a Global Mercury Assessment Working Group to assist in the drafting and finalization of this report, first through a comment round by mail, then through a meeting of the Working Group, which took place 9-13 September 2002 in Geneva, Switzerland. The Working Group was open-ended and consisted of members nominated by Governments, intergovernmental organizations and non-governmental organizations.

38. This report will be forwarded to the Governing Council for consideration at its 22nd session in February 2003. By having initiated the development of this assessment report, the Governing Council will have a better basis for considering if any international action on mercury is called for in order to promote environmentally sound management of mercury and its compounds. The report will contribute to increased awareness and understanding among decision makers of the major issues related to mercury and its compounds, thereby facilitating the debate on the issue at the next session of the Governing Council.

CHAPTER 2 – Chemistry

39. Mercury occurs naturally in the environment and exists in a large number of forms. Like lead or cadmium, mercury is a constituent element of the earth, a heavy metal. In pure form, it is known alternatively as "elemental" or "metallic" mercury (also expressed as Hg(0) or Hg^0). Mercury is rarely found in nature as the pure, liquid metal, but rather within compounds and inorganic salts. Mercury can be bound to other compounds as monovalent or divalent mercury (also expressed as Hg(I) and Hg(II) or Hg^{2+}, respectively). Many inorganic and organic compounds of mercury can be formed from Hg(II).

40. Elemental mercury is a shiny, silver-white metal that is a liquid at room temperature and is traditionally used in thermometers and some electrical switches. If not enclosed, at room temperature some of the metallic mercury will evaporate and form mercury vapours. Mercury vapours are colourless and odourless. The higher the temperature, the more vapours will be released from liquid metallic mercury. Some people who have breathed mercury vapours report a metallic taste in their mouths.

41. Mercury is mined as mercuric sulphide (cinnabar ore). Through history, deposits of cinnabar have been the source ores for commercial mining of metallic mercury. The metallic form is refined from mercuric sulphide ore by heating the ore to temperatures above 540 ° C. This vaporises the mercury in the ore, and the vapours are then captured and cooled to form the liquid metal mercury.

42. Inorganic mercuric compounds include mercuric sulphide (HgS), mercuric oxide (HgO) and mercuric chloride ($HgCl_2$). These mercury compounds are also called mercury salts. Most inorganic mercury compounds are white powders or crystals, except for mercuric sulphide, which is red and turns black after exposure to light. Some mercury salts (such as $HgCl_2$) are sufficiently volatile to exist as an atmospheric gas. However, the water solubility and chemical reactivity of these inorganic (or divalent) mercury gases lead to much more rapid deposition from the atmosphere than for elemental mercury. This results in sig-

nificantly shorter atmospheric lifetimes for these divalent mercury gases than for the elemental mercury gas.

43. When mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organomercurials. There is a potentially large number of organic mercury compounds (such as dimethylmercury, phenylmercury, ethylmercury and methylmercury); however, by far the most common organic mercury compound in the environment is methylmercury. Like the inorganic mercury compounds, both methylmercury and phenylmercury exist as "salts" (for example, methylmercuric chloride or phenylmercuric acetate). When pure, most forms of methylmercury and phenylmercury are white crystalline solids. Dimethylmercury, however, is a colourless liquid.

44. Several forms of mercury occur naturally in the environment. The most common natural forms of mercury found in the environment are metallic mercury, mercuric sulphide, mercuric chloride, and methylmercury. Some micro-organisms and natural processes can change the mercury in the environment from one form to another.

45. Elemental mercury in the atmosphere can undergo transformation into inorganic mercury forms, providing a significant pathway for deposition of emitted elemental mercury.

46. The most common organic mercury compound that micro-organisms and natural processes generate from other forms is methylmercury. Methylmercury is of particular concern because it can build up (bioaccumulate and biomagnify) in many edible freshwater and saltwater fish and marine mammals to levels that are many thousands of times greater than levels in the surrounding water.

47. Methylmercury can be formed in the environment by microbial metabolism (biotic processes), such as by certain bacteria, and by chemical processes that do not involve living organisms (abiotic processes). Although, it is generally believed that its formation in nature is predominantly due to biotic processes. Significant direct anthropogenic (or human generated) sources of methylmercury are currently not known, although historic sources have existed. Indirectly, however, anthropogenic releases contribute to the methylmercury levels found in nature because of the transformation of other forms. Examples of direct release of organic mercury compounds are the Minamata methylmercury-poisoning event that occurred in the 1950's where organic mercury by-products of industrial-scale acetaldehyde production were discharged in the local bay, and the Iraqi poisoning events where wheat treated with a seed dressing containing organic mercury compounds were used for bread. Also, new research has shown that methylmercury can be released directly from municipal waste landfills (Lindberg *et al.*, 2001) and sewage treatment plants (Sommar *et al.*, 1999), but the general significance of this source is still uncertain.

48. Being an element, mercury cannot be broken down or degraded into harmless substances. Mercury may change between different states and species in its cycle, but its simplest form is elemental mercury, which itself is harmful to humans and the environment. Once mercury has been liberated from either ores or from fossil fuel and mineral deposits hidden in the earth's crust and released into the biosphere, it can be highly mobile, cycling between the earth's surface and the atmosphere. The earth's surface soils, water bodies and bottom sediments are thought to be the primary biospheric sinks for mercury.

Mercury exists in the following main states under natural conditions

- As metallic vapour and liquid/elemental mercury;
- Bound in mercury containing minerals (solid);
- As ions in solution or bound in ionic compounds (inorganic and organic salts);
- As soluble ion complexes;
- As gaseous or dissolved non-ionic organic compounds;
- Bound to inorganic or organic particles/matter by ionic, electrophilic or lipophilic adsorption.

Significance of mercury speciation

49. The different forms mercury exists in (such as elemental mercury vapour, methylmercury or mercuric chloride) are commonly designated "species". As mentioned above, the main groups of mercury species are elemental mercury, inorganic and organic mercury forms. Speciation is the term commonly used to represent the distribution of a quantity of mercury among various species.

50. Speciation plays an important part in the toxicity and exposure of mercury to living organisms. Among other things, the species influence:

- The physical availability for exposure - if mercury is tightly bound to in-absorbable material, it cannot be readily taken up (e.g. into the blood stream of the organism);
- The internal transport inside the organism to the tissue on which it has toxic effects - for example the crossing of the intestinal membrane or the blood-brain barrier;
- Its toxicity (partly due to the above mentioned);
- Its accumulation, bio-modification, detoxification in – and excretion from – the tissues;
- Its bio-magnification on its way up the trophic levels of the food chain (an important feature particularly for methylmercury).

51. Speciation also influences the transport of mercury within and between environmental compartments including the atmosphere and oceans, among others. For example, the speciation is a determining factor for how far from the source mercury emitted to air is transported. Mercury adsorbed on particles and ionic (e.g. divalent) mercury compounds will fall on land and water mainly in the vicinity of the sources (local to regional distances), while elemental mercury vapour is transported on a hemispherical/global scale making mercury emissions a global concern. Another example is the so-called "polar sunrise mercury depletion incidence", where the transformation of elemental mercury to divalent mercury is influenced by increased solar activity and the presence of ice crystals, resulting in a substantial increase in mercury deposition during a three month period (approximately March to June).

52. Moreover, speciation is very important for the controllability of mercury emissions to air. For example, emissions of inorganic mercuric compounds (such as mercuric chloride) are captured reasonably well by some control devices (such as wet-scrubbers), while capture of elemental mercury tends to be low for most emission control devices.

CHAPTER 3 – Toxicology

53. The toxicity of mercury depends on its chemical form, and thus symptoms and signs are rather different in exposure to elemental mercury, inorganic mercury compounds, or organic mercury compounds (notably alkylmercury compounds such as methylmercury and ethylmercury salts, and dimethylmercury). The sources of exposure are also markedly different for the different forms of mercury. For alkylmercury compounds, among which methylmercury is by far the most important, the major source of exposure is diet, especially fish and other seafood. For elemental mercury vapour, the most important source for the general population is dental amalgam, but exposure at work may in some situations exceed this by many times. For inorganic mercury compounds, diet is the most important source for the majority of people. However, for some segments of populations, use of skin-lightening creams and soaps that contain mercury, and use of mercury for cultural/ritualistic purposes or in traditional medicine, can also result in substantial exposures to inorganic or elemental mercury.

54. While it is fully recognised that mercury and its compounds are highly toxic substances for which potential impacts should be considered carefully, there is ongoing debate on how toxic these substances, especially methylmercury, are. New findings during the last decade indicate that toxic effects may be taking place at lower concentrations than previously thought, and potentially larger parts of the global population may be affected. As the mechanisms of subtle toxic effects – and proving whether such effects are taking place – are extremely complex issues, a complete understanding has so far not been reached on this very important question.

Methylmercury

55. Of the organic mercury compounds, methylmercury occupies a special position in that large populations are exposed to it, and its toxicity is better characterized than that of other organic mercury compounds. Within the group of organic mercury compounds, alkylmercury compounds (especially ethylmercury and methylmercury) are thought to be rather similar as to toxicity (and also historical use as pesticides), while other organic mercury compounds, such as phenylmercury, resemble more inorganic mercury in their toxicity.

56. Methylmercury is a well-documented neurotoxicant, which may in particular cause adverse effects on the developing brain. Moreover, this compound readily passes both the placental barrier and the blood-brain barrier, therefore, exposures during pregnancy are of highest concern. Also, some studies suggest that even small increases in methylmercury exposures may cause adverse effects on the cardiovascular system, thereby leading to increased mortality. Given the importance of cardiovascular diseases worldwide, these findings, although yet to be confirmed, suggest that methylmercury exposures need close attention and additional follow-up. Moreover, methylmercury compounds are considered possibly carcinogenic to humans (group 2B) according to the International Agency for Research on Cancer (IARC, 1993), based on their overall evaluation.

Elemental mercury and inorganic mercury compounds

57. The main route of exposure for elemental mercury is by inhalation of the vapours. About 80 percent of inhaled vapours are absorbed by the lung tissues. This vapour also easily penetrates the blood-brain barrier and is a well-documented neurotoxicant. Intestinal absorption of elemental mercury is low. Elemental mercury can be oxidized in body tissues to the inorganic divalent form.

58. Neurological and behavioural disorders in humans have been observed following inhalation of elemental mercury vapour. Specific symptoms include tremors, emotional lability, insomnia, memory loss, neuromuscular changes, and headaches. In addition, there are effects on the kidney and thyroid. High exposures have also resulted in death. With regard to carcinogenicity, the overall evaluation, according to IARC (1993), is that metallic mercury and inorganic mercury compounds are not classifiable as to carcinogenicity to humans (group 3). A critical effect on which risk assessment could be based is therefore the neurotoxic effects, for example the induction of tremor. The effects on the kidneys (the renal tubule) should also be considered; they are the key endpoint in exposure to inorganic mercury compounds. The effect may well be reversible, but as the exposure to the general population tends to be continuous, the effect may still be relevant.

Summary of effect levels

59. To put the level of exposures for methylmercury in perspective, for the most widely accepted non-lethal adverse effect (neurodevelopmental effects), the United States (US) National Research Council (NRC, 2000) has estimated the benchmark dose (BMD) to be 58 micrograms per litre (µg/l) total mercury in cord blood (or 10 micrograms per gram (µg/g) total mercury in maternal hair) using data from the Faroe Islands study of human mercury exposures (Grandjean et al., 1997). This BMD level is the lower 95% confidence limit for the exposure level that causes a doubling of a 5% prevalence of abnormal neurological performance (developmental delays in attention, verbal memory and language) in children exposed in-utero in the Faroe Islands study. These are the tissue levels estimated to result from an average daily intake of about 1 µg methylmercury per kg body weight per day (1 µg/kg body weight per day).

60. Other adverse effects have been seen in humans with less reliability or at much higher exposures. For methylmercury, effects have been seen on the adult nervous system, on cardiovascular disease, on cancer incidence and on genotoxicity. Also, effects have been reported on heart rate variability and blood pressure in 7 year-old children exposed prenatally, and on cardiovascular mortality in adults. For elemental mercury and inorganic mercury compounds, effects have been seen on: the excretion of low molecular weight proteins; on enzymes associated with thyroid function; on spontaneous abortion rates; genotoxicity; respiratory system; gastrointestinal (digestion) system; liver; immune system; and the skin.

Dietary considerations

61. Fish are an extremely important component of the human diet in many parts of the world and provide nutrients (such as protein, omega-3 fatty acids and others) that are not easily replaced. Mercury is a major threat to this food supply. Certainly, fish with low methylmercury levels are intrinsically more healthful for consumers than fish with higher levels of methylmercury, if all other factors are equal.

62. There is limited laboratory evidence suggesting that several dietary components might reduce (e.g. selenium, vitamin E, omega-3 fatty acids) or enhance (e.g. alcohol) mercury's toxicity for some end-points. However, conclusions cannot be drawn from these data at this time.

CHAPTER 4 - Current mercury exposure and risk evaluations for human health

63. As mentioned earlier, the general population is primarily exposed to methylmercury through the diet (especially fish) and to elemental mercury vapours due to dental amalgams. Depending on local mercury pollution load, substantial additional contributions to the intake of total mercury can occur through air and water. Also, personal use of skin-lightening creams and soaps, mercury use for religious, cultural and ritualistic purposes, the presence of mercury in some traditional medicines (such as certain traditional Asian remedies) and mercury in the home or working environment can result in substantial elevations of human mercury exposure. For example, elevated air levels in homes have resulted from mercury spills from some old gas meters and other types of spills. Also, elevated mercury levels in the working environment have been reported for example in chlor-alkali plants, mercury mines, thermometer factories, refineries and dental clinics, as well as in mining and manufacturing of gold extracted with mercury. Additional exposures result from the use of Thimerosal/Thiomersal (ethylmercury thiosalicylate) as a preservative in some vaccines and other pharmaceuticals. The relative impacts of mercury from local pollution, occupational exposure, certain cultural and ritualistic practices and some traditional medicines may today vary considerably between countries and regions in the world, and are significant in some regions.

64. The chapter gives examples of data on total mercury and methylmercury exposures primarily from fish diets, but also other sources in different parts of the world, including Sweden, Finland, the United States of America (USA), the Arctic, Japan, China, Indonesia, Papua New Guinea, Thailand, Republic of Korea, Philippines, the Amazonas and French Guyana. For example, in a study of a representative group of about 1700 women in the USA (aged 16-49 years) for years 1999-2000, about 8 percent of the women had mercury concentrations in blood and hair exceeding the levels corresponding to the US EPA's reference dose (an estimate of a safe dose). As shown in the chapter, data indicate exposures are generally higher in Greenland, Japan and some other areas as compared to the USA.

65. In some of these countries and areas, local and regional mercury depositions have affected the mercury contamination levels over the years and countermeasures have been taken during the last decades to reduce national emissions. Mercury emissions are, however, distributed over long distances in the atmosphere and oceans. This means that even countries with minimal mercury emissions, and other areas situated remotely from dense human activity, may be adversely affected. For example, high mercury exposures have been observed in the Arctic far distances from any significant sources.

66. Data on mercury concentrations in fish have been submitted from a number of nations and international organisations. Additionally, many investigations of mercury levels in fish are reported in the literature. Submitted data, giving examples of mercury concentrations in fish from various locations in the world, are summarised in the chapter. The mercury concentrations in various fish species are generally from about 0.05 to 1.4 milligrams of mercury per kilogram of fish tissue (mg/kg) depending on factors such as pH and redox potential of the water, and species, age and size of the fish. Since mercury biomagnifies in the aquatic food web, fish higher on the food chain (or of higher trophic level) tend to have higher levels of mercury. Hence, large predatory fish, such as king mackeral, pike, shark, swordfish, walleye, barracuda, large tuna (as opposed to the small tuna usually used for canned tuna), scabbard and marlin, as well as seals and toothed whales, contain the highest concentrations. The available data indicate that mercury is present all over the globe (especially in fish) in concentrations that adversely affect

human beings and wildlife. These levels have led to consumption advisories (for fish, and sometimes marine mammals) in a number of countries, warning people, especially sensitive subgroups (such as pregnant women and young children), to limit or avoid consumption of certain types of fish from various waterbodies. Moderate consumption of fish (with low mercury levels) is not likely to result in exposures of concern. However, people who consume higher amounts of contaminated fish or marine mammals may be highly exposed to mercury and are therefore at risk.

CHAPTER 5 – Impacts of mercury on the environment

Build-up of mercury in food webs

67. A very important factor in the impacts of mercury to the environment is its ability to build up in organisms and up along the food chain. Although all forms of mercury can accumulate to some degree, methylmercury is absorbed and accumulates to a greater extent than other forms. Inorganic mercury can also be absorbed, but is generally taken up at a slower rate and with lower efficiency than is methylmercury. The biomagnification of methylmercury has a most significant influence on the impact on animals and humans. Fish appear to bind methylmercury strongly, nearly 100 percent of mercury that bioaccumulates in predator fish is methylmercury. Most of the methylmercury in fish tissue is covalently bound to protein sulfhydryl groups. This binding results in a long half-life for elimination (about two years). As a consequence, there is a selective enrichment of methylmercury (relative to inorganic mercury) as one moves from one trophic level to the next higher trophic level.

Bioaccumulation and biomagnification

The term **bioaccumulation** refers to the net accumulation over time of metals within an organism from both biotic (other organisms) and abiotic (soil, air, and water) sources.

The term **biomagnification** refers to the progressive build up of some heavy metals (and some other persistent substances) by successive trophic levels – meaning that it relates to the concentration ratio in a tissue of a predator organism as compared to that in its prey (AMAP, 1998).

68. In contrast to other mercury compounds the elimination of methylmercury from fish is very slow. Given steady environmental concentrations, mercury concentrations in individuals of a given fish species tend to increase with age as a result of the slow elimination of methylmercury and increased intake due to changes in trophic position that often occur as fish grow to larger sizes (i.e., the increased fish-eating and the consumption of larger prey items). Therefore, older fish typically have higher mercury concentrations in the tissues than younger fish of the same species.

69. The mercury concentrations are lowest in the smaller, non-predatory fish and can increase many-fold on the way up the food chain. Apart from the concentration in food, other factors affect the bioaccumulation of mercury. Of most importance are the rates of methylation and demethylation by mercury methylating bacteria (e.g., sulphate reducers). When all of these factors are combined, the net methylation rate can strongly influence the amount of methylmercury that is produced and available for accumulation and retention by aquatic organisms. As described in chapter 2, several parameters in the aquatic environment influence the methylation of mercury and thereby its biomagnification. While much is generally known about mercury bioaccumulation and biomagnification, the process is extremely complex and involves complicated biogeochemical cycling and ecological interactions. As a result, although accumulation/magnification can be observed, the extent of mercury biomagnification in fish is not easily predicted across different sites.

70. At the top levels of the aquatic food web are fish-eating species, such as humans, seabirds, seals and otters. The larger wildlife species (such as eagles, seals) prey on fish that are also predators, such as trout and salmon, whereas smaller fish-eating wildlife (such as kingfishers) tend to feed on the smaller forage fish. In a study of fur-bearing animals in Wisconsin, the species with the highest tissue levels of

mercury were otter and mink, which are top mammalian predators in the aquatic food chain. Top avian predators of aquatic food chains include raptors such as the osprey and bald eagle. Thus, mercury is transferred and accumulated through several food web levels (US EPA, 1997). Aquatic food webs tend to have more levels than terrestrial webs, where wildlife predators rarely feed on each other, and therefore the aquatic biomagnification typically reaches higher values.

Mercury compounds toxic to wildlife

71. Methylmercury is a central nervous system toxin, and the kidneys are the organs most vulnerable to damage from inorganic mercury. Severe neurological effects were already seen in animals in the notorious case from Minamata, Japan, prior to the recognition of the human poisonings, where birds experienced severe difficulty in flying, and exhibited other grossly abnormal behaviour. Significant effects on reproduction are also attributed to mercury, and methylmercury poses a particular risk to the developing fetus since it readily crosses the placental barrier and can damage the developing nervous system.

72. In birds, adverse effects of mercury on reproduction can occur at egg concentrations as low as 0.05 to 2.0 mg/kg (wet weight). Eggs of certain Canadian species are already in this range, and concentrations in the eggs of several other Canadian species continue to increase and are approaching these levels.

73. The levels of mercury in Arctic ringed seals and beluga whales have increased by 2 to 4 times over the last 25 years in some areas of the Canadian Arctic and Greenland. In warmer waters as well, predatory marine mammals may also be at risk. In a study of Hong Kong's population of hump-backed dolphins, mercury was identified as a particular health hazard, more than other heavy metals.

Vulnerable ecosystems

74. Recent evidence suggests that mercury is responsible for a reduction of micro-biological activity vital to the terrestrial food chain in soils over large parts of Europe – and potentially in many other places in the world with similar soil characteristics. Preliminary critical limits to prevent ecological effects due to mercury in organic soils have been set at 0.07-0.3 mg/kg for the total mercury content in soil.

75. On the global scale, the Arctic region has been in focus recently because of the long-range transport of mercury. However, impacts from mercury are by no means restricted to the Arctic region of the world. The same food web characteristics - and a similar dependence on a mercury contaminated food source - are found in specific ecosystems and human communities in many countries of the world, particularly in places where a fish diet is predominant.

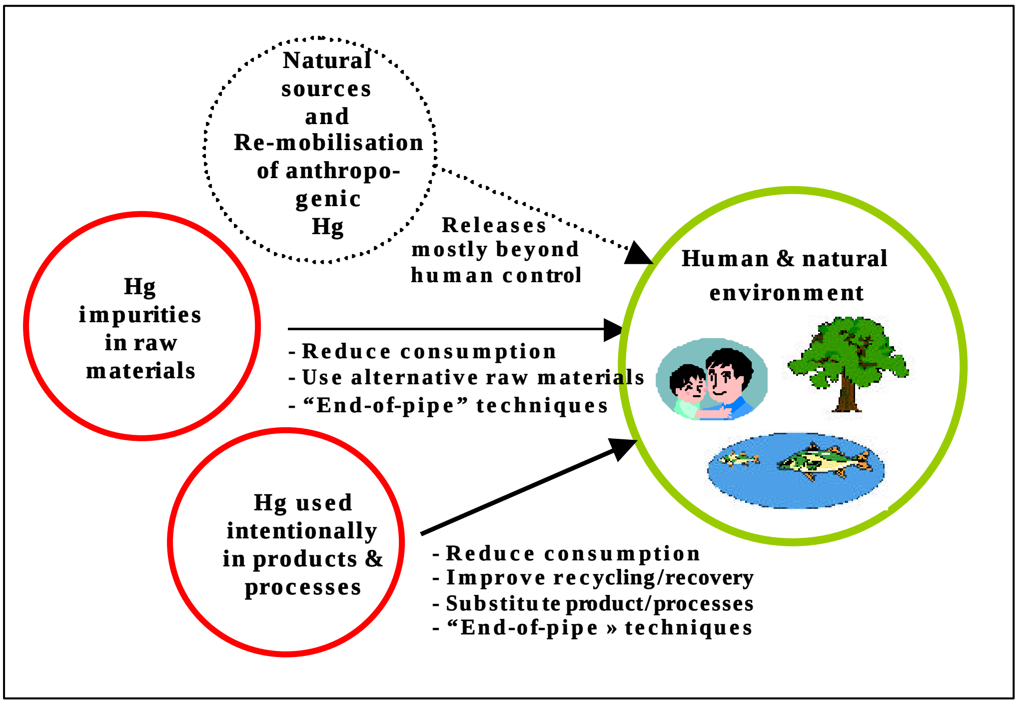
76. Rising water levels associated with global climate change may also have implications for the methylation of mercury and its accumulation in fish. For example, there are indications of increased formation of methylmercury in small, warm lakes and in many newly flooded areas.

CHAPTER 6 – Sources and cycling of mercury to the global environment

77. The releases of mercury to the biosphere can be grouped in four categories:

- Natural sources - releases due to natural mobilisation of naturally occurring mercury from the Earth's crust, such as volcanic activity and weathering of rocks;
- Current anthropogenic (associated with human activity) releases from the mobilisation of mercury impurities in raw materials such as fossil fuels – particularly coal, and to a lesser extent gas and oil – and other extracted, treated and recycled minerals;
- Current anthropogenic releases resulting from mercury used intentionally in products and processes, due to releases during manufacturing, leaks, disposal or incineration of spent products or other releases;
- Re-mobilisation of historic anthropogenic mercury releases previously deposited in soils, sediments, water bodies, landfills and waste/tailings piles.

78. The figure below shows these release categories with main types of possible control mechanisms.



79. The recipients of mercury releases to the environment include the atmosphere, water environments (aquatic) and soil environments (terrestrial). There are continuing interactions – fluxes of mercury – between these compartments. The speciation – the chemical form – of the released mercury varies depending on the source types and other factors. This also influences the impacts on human health and environment as different mercury species have different toxicity.

80. Given the understanding of the global mercury cycle, current releases add to the global pool of mercury in the biosphere – mercury that is continuously mobilised, deposited on land and water surfaces, and re-mobilised. Being an element, mercury is persistent – it cannot be broken down to less toxic substances in the environment. The only long-term sinks for removal of mercury from the biosphere are deep-sea sediments and, to a certain extent, controlled landfills, in cases where the mercury is physio-chemically immobilised and remains undisturbed by anthropogenic or natural activity (climatic and geological). This also implies that even as the anthropogenic releases of mercury are gradually eliminated, decreases in some mercury concentrations – and related environmental improvements – will occur only slowly, most likely over several decades or longer. However, improvements may occur more quickly in specific locations or regions that are largely impacted by local or regional sources.

Local releases – global effects

81. The origins of atmospheric mercury deposition (flow of mercury from air to land and oceans) are local and regional as well as hemispherical or global. Several large studies have supported the conclusion that, in addition to local sources (such as chlor-alkali production, coal combustion and waste incineration facilities), the general background concentration of mercury in the global atmosphere contributes significantly to the mercury burden at most locations. Similarly, virtually any local source contributes to the background concentration – the global mercury pool in the biosphere - much of which represents anthropogenic releases accumulated over the decades. Also, the ocean currents are media for long-range mercury transport, and the oceans are important dynamic sinks of mercury in the global cycle.

82. The majority of atmospheric anthropogenic emissions are released as gaseous elemental mercury. This is capable of being transported over very long distances with the air masses. The remaining part of air emissions are in the form of gaseous divalent compounds (such as $HgCl_2$) or bound to particles present in the emission gas. These species have a shorter atmospheric lifetime than elemental vapour and will deposit via wet or dry processes within roughly 100 to 1000 kilometers. However, significant conversion

between mercury species may occur during atmospheric transport, which will affect the transport distance.

83. The atmospheric residence time of elemental mercury is in the range of months to roughly one year. This makes transport on a hemispherical scale possible and emissions in any continent can thus contribute to the deposition in other continents. For example, based on modelling of the intercontinental mercury transport performed by EMEP/MSC-E (Travnikov and Ryaboshapko, 2002), up to 50 percent of anthropogenic mercury deposited to North America is from external sources. Similarly, contributions of external sources to anthropogenic mercury depositions to Europe and Asia were estimated to be about 20 percent and 15 percent, respectively.

84. Furthermore, as mentioned, mercury is also capable of re-emissions from water and soil surfaces. This process greatly enhances the overall residence time of mercury in the environment. Recent findings by Lindberg *et al.* (2001) indicate re-emission rates of approximately 20 percent over a two-year period, based on stable mercury isotope measurements in north-western Ontario, Canada.

Anthropogenic sources of mercury releases

85. A large portion of the mercury present in the atmosphere today is the result of many years of releases due to anthropogenic activities. The natural component of the total atmospheric burden is difficult to estimate, although a recent study (Munthe *et al.*, 2001) has suggested that anthropogenic activities have increased the overall levels of mercury in the atmosphere by roughly a factor of 3.

86. While there are some natural emissions of mercury from the earth's crust, anthropogenic sources are the major contributors to releases of mercury to the atmosphere, water and soil.

Examples of important sources of anthropogenic releases of mercury

Releases from mobilisation of mercury impurities:

- Coal-fired power and heat production (largest single source to atmospheric emissions)
- Energy production from other fossil carbon fuels
- Cement production (mercury in lime)
- Mining and other metallurgic activities involving the extraction and processing of virgin and recycled mineral materials, for example production of:
  - iron and steel
  - ferromanganese
  - zinc
  - gold
  - other non-ferrous metals

Releases from intentional extraction and use of mercury:

- Mercury mining
- Small-scale gold and silver mining (amalgamation process)
- Chlor-alkali production
- Use of fluorescent lamps, various instruments and dental amalgam fillings.
- Manufacturing of products containing mercury, for example:
  - thermometers
  - manometers and other instruments
  - electrical and electronic switches

Releases from waste treatment, cremation etc. (originating from both impurities and intentional uses of mercury):

- Waste incineration (municipal, medical and hazardous wastes)
- Landfills
- Cremation
- Cemeteries (release to soil)

87. There are significant uncertainties in the available release inventories, not only by source, but also by country. The best available estimates of mercury emissions to air from various significant sources are shown in the table below.

Table Estimates of global atmospheric releases of mercury from a number of major anthropogenic sources in 1995 (metric tons/year). Releases to other media are not accounted for here. ***1.**

Continent	**Stationary combustion**	**Non-ferrous metal production *5**	**Pig iron and steel production**	**Cement production**	**Waste disposal *2**	**Artisanal gold mining *4**	**Sum, quantified sources *3**
Europe	186	15	10	26	12		250
Africa	197	7.9	0.5	5.2			210
Asia	**860**	**87**	**12**	**82**	33		1070
North America	105	25	4.6	13	**66**		210
South America	27	25	1.4	5.5			60
Australia and Oceania	100	4.4	0.3	0.8	0.1		100
Sum, quantified sources, 1995 ***3**,**4**	1470	170	30	130	110	300	1900 +300
Based on references:	Pirrone *et al*. (2001)	Pirrone *et al*. (2001)	Pirrone *et al*. (2001)	Pirrone *et al*. (2001)	Pirrone *et al*. (2001)	Lacerda (1997)	

1 Note that releases to aquatic and terrestrial environments - as well as atmospheric releases from a number of other sources - are not included in the table, because no recent global estimates have been made. See chapter 6 for description of this issue.

2 Considered underestimated by authors of the inventory, see notes to table 6.10.

3 Represents total of the sources mentioned in this table, not all known sources. Sums are rounded and may therefore not sum up precisely.

4 Estimated emissions from artisanal gold mining refer to late 1980's/early 1990's situation. A newer reference (MMSD, 2002) indicates that mercury consumption for artisanal gold mining - and thereby most likely also mercury releases - may be even higher than presented here.

5 Production of non-ferrous metals releasing mercury, including mercury, zinc, gold, lead, copper, nickel.

88. The emissions from stationary combustion of fossil fuels (especially coal) and incineration of waste materials accounts for approximately 70 percent of the total quantified atmospheric emissions from major anthropogenic sources. As combustion of fossil fuels is increasing in order to meet the growing energy demands of both developing and developed nations, mercury emissions can be expected to increase accordingly in the absence of the deployment of control technologies or the use of alternative energy sources. Control technologies have been developed for coal combustion plants and waste incinerators with the primary intention of addressing acidifying substances (especially SO_2 and NO_X), and particulate matter (PM). Such existing technologies may provide some level of mercury control, but when viewed at the global level, currently these controls result in only a small reduction of mercury from these sources. Many control technologies are significantly less effective at reducing emissions of elemental mercury compared to other forms. Optimised technologies for mercury control are being developed and demonstrated, but are not yet commercially deployed.

89. Available global estimates of atmospheric emissions from waste incineration, as well as other releases originating from intentional uses of mercury in processes and products, are deemed underestimated, and to some degree incomplete. However, recorded virgin mercury production has been decreasing from about 6000 to about 2000 metric tons per year during the last two decades, and consequently, related releases from mining and usage of mercury may also be declining.

90. Anthropogenic emissions from a number of major sources have decreased during the last decade in North America and Europe due to reduction efforts. Also, total anthropogenic emissions to air have been declining in some developed countries in the last decade. For example, Canadian emissions were reduced from about 33 metric tons to 6 metric tons between 1990 and 2000.

Natural sources of mercury releases

91. Natural sources include volcanoes, evaporation from soil and water surfaces, degradation of minerals and forest fires. The natural mercury emissions are beyond our control, and must be considered part of our local and global living environment. It is necessary to keep this source in mind, however, as it does contribute to the environmental mercury levels. In some areas of the world, the mercury concentrations in the Earth's crust are naturally elevated, and contribute to elevated local and regional mercury concentrations in those areas.

92. Today's emissions of mercury from soil and water surfaces are composed of both natural sources and re-emission of previous deposition of mercury from both anthropogenic and natural sources. This makes it very difficult to determine the actual natural mercury emissions.

93. Published estimates of natural versus anthropogenic mercury emissions show significant variation, although more recent efforts have emphasized the importance of human contributions. Attempts to directly measure natural emissions are ongoing. Nonetheless, available information indicates that natural sources account for less than 50 percent of the total releases.

94. On average around the globe, there are indications that anthropogenic emissions of mercury have resulted in deposition rates today that are 1.5 to 3 times higher than those during pre-industrial times. In and around industrial areas the deposition rates have increased by 2 to 10 times during the last 200 years.

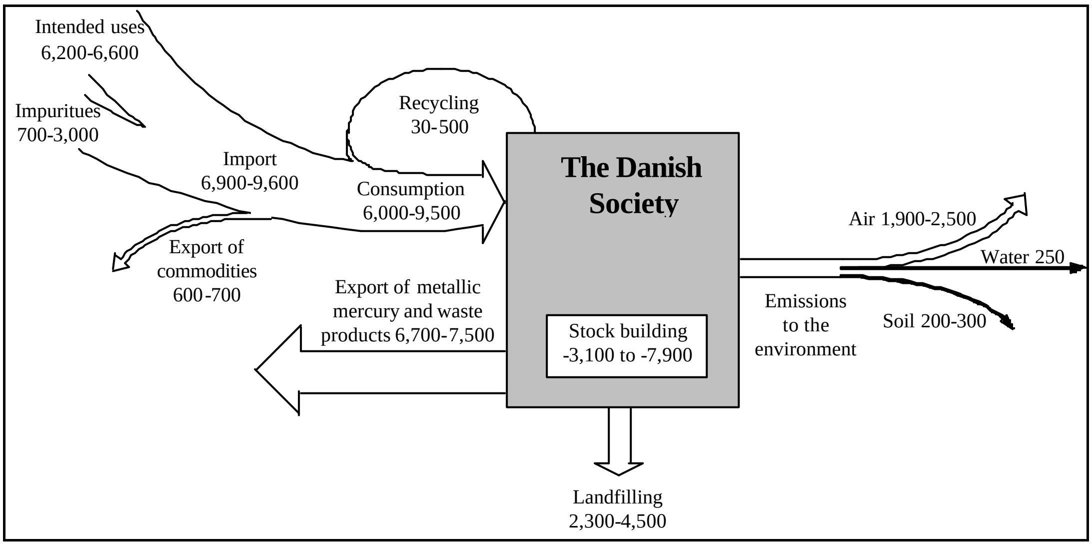
Contributions from intentional uses versus impurities in high volume materials

95. Regarding anthropogenic releases, the relative importance of intentional uses versus mobilisation of mercury impurities varies between countries and regions, particularly depending on:

- State of substitution of intentional uses (products and processes);
- Reliance on fossil fuels for energy production, particularly coal, and the presence of controls for other pollutants, which also reduce mercury emissions;
- Extent of mining and mineral extraction industry;
- Waste disposal pattern – incineration/landfilling;
- State of implementation of release control technologies in power production, waste incineration and various industrial processes.

96. For a number of countries, estimated contributions of intentional uses vary between 10 and 80 percent of the total domestic emissions to air, depending on the influence of the factors listed above. Rough estimates of distribution by main anthropogenic source types in each of these countries are shown in the chapter.

97. As an illustration, the figure below shows the overall turnover of mercury in the Danish society in 1992/93 in kilograms mercury/year (based on Maag *et al.*, 1996). (Note that inputs and outputs in the figure do not balance because outputs reflect higher inputs from previous years. Net change in stocks was negative.)



98. Denmark is a quite small country with relatively accurate monitoring of the flows of products and waste in the economy and the environment. Therefore, it has been possible to perform rather detailed balances, so-called substance flow assessments for mercury, which provide useful information on the contributions from different sectors to the total mercury burden in society and the environment. As shown in the figure, the majority of the input – more than two thirds – originated from intentional uses (chlor-alkali production and products), and the contributions from intentional uses to releases to air in 1992/93 could roughly be estimated at 50-80 percent of the total releases to air from Denmark. It should be noted that primary mineral extraction and processing is not as large a sector in Denmark, as in many other countries.

99. Examples of national distributions of anthropogenic mercury releases from different individual source types are given in the chapter. In countries where mercury mining or intentional use of mercury for small-scale gold mining is taking place, these sources can be significant.

CHAPTER 7 – Current production and use of mercury

Origin of mercury

100. Mercury is a natural component of the earth, with an average abundance of approximately 0.05 mg/kg in the earth's crust, with significant local variations. Mercury ores that are mined generally contain about one percent mercury, although the strata mined in Spain typically contain up to 12-14 percent mercury. While about 25 principal mercury minerals are known, virtually the only deposits that have been harvested for the extraction of mercury are cinnabar. Mercury is also present at very low levels throughout the biosphere. Its absorption by plants may account for the presence of mercury within fossil fuels like coal, oil, and gas, since these fuels are conventionally thought to be formed from geologic transformation of organic residues.

Sources of mercury to the market

101. The mercury available on the world market is supplied from a number of different sources, including (not listed in order of importance):

- Mine production of primary mercury (meaning extracted from ores within the earth's crust):
  - either as the main product of the mining activity,
  - or as by-product of mining or refining of other metals (such as zinc, gold, silver) or minerals;
- Recovered primary mercury from refining of natural gas (actually a by-product, when marketed, however, is not marketed in all countries);
- Reprocessing or secondary mining of historic mine tailings containing mercury;
- Recycled mercury recovered from spent products and waste from industrial production processes. Large amounts ("reservoirs") of mercury are "stored" in society within products still in use and "on the users' shelves";

- Mercury from government reserve stocks, or inventories;
- Private stocks (such as mercury in use in chlor-alkali and other industries), some of which may later be returned to the market.

102. The mining and other mineral extraction of primary mercury constitute the human mobilisation of mercury for intentional use in products and processes. Recycled mercury and mercury from stocks can be regarded as an anthropogenic re-mobilisation of mercury previously extracted from the Earth.

Continued mining of primary mercury

103. Despite a decline in global mercury consumption (global demand is less than half of 1980 levels), supply from competing sources and low prices, production of mercury from mining is still occurring in a number of countries. Spain, China, Kyrgyzstan and Algeria have dominated this activity in recent years, and several of the mines are state-owned. The table below gives information on recorded global primary production of mercury since 1981. There are also reports of small-scale, artisanal mining of mercury in China, Russia (Siberia), Outer Mongolia, Peru, and Mexico. It is likely that this production serves robust local demand for mercury, often for artisanal mining of gold – whether legal or illegal. Such mercury production would require both accessible mercury ores and low-cost labor in order for it to occur despite low-priced mercury available in the global commodity market.

Period	**1981-1985**	**1986-1989**	**1990-1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Recorded annual, global primary production (in metric tons)	5500-7100	4900-6700	3300-6100	2600-2800	2500-2900	2000-2800	2100-2200	1800

Sources: See section 7.2.1.

Large supplies of recycled mercury may be marketed

104. Large quantities of mercury have come onto the market as a result of ongoing substitution and closing of mercury-based chlor-alkali production in Europe and other regions. Market analysis indicates that 700 - 900 metric tons per year of recycled mercury (corresponding to about 30 percent of the recorded primary production) has been marketed globally since the mid-1990's, of which the majority originated from chlor-alkali production facilities. However, to the extent there remains a legitimate demand for mercury, the re-use and recycling of mercury replaces the mining and smelting of virgin mercury, which would involve additional releases and would result in mobilising new mercury into the market and the environment.

105. The preference for reuse and recycling of mercury over mining - especially in the context of large mercury inventories coming onto the market - is complicated by the generally accepted economic rule that an **excess** supply of mercury drives the market price lower, which in turn encourages additional use or waste of mercury. For this reason, certain precautions are being taken, as described below.

106. Within the current decade and beyond, vast supplies of mercury will become available from conversion or shutdown of chlor-alkali facilities using the mercury process, as many European countries press for a phase-out of this process before 2010. From the European Union alone, this may introduce up to 13,000 metric tons of additional mercury to the market (equal to some 6-12 years of primary mercury production). In response to this potential glut of mercury, Euro Chlor, which represents the European chlor-alkali industry, has signed a contractual agreement with Miñas de Almadén in Spain. The agreement provides that Miñas de Almadén will buy the surplus mercury from the West-European chlor-alkali plants and put it on the market in place of mercury Almadén would otherwise have mined. All EU members of Euro Chlor have agreed to sell their surplus mercury to Almadén according to this agreement, and Euro Chlor believes most of the central and eastern European chlorine producers will also commit to this agreement. While this agreement clearly represents an effort by all parties to responsibly address the problem of surplus mercury, some people have the view that there are not yet adequate controls on where this mercury would be sold or how it would be used.

107. Similarly, large reserve stocks of mercury held by various governments have become superfluous, and are subject to future sales on the world market if approved by the relevant national authorities. This is the case in the USA, for example, which holds a 4,435 metric ton inventory of mercury. The sale of this mercury has been suspended since 1994, awaiting a determination of its potential environmental and market impacts. Prior to that, however, the sale of some of these stocks contributed significantly to the supply of mercury on the domestic US-market, and to exports as well. US government sales were equivalent to 18 to 97 percent of the domestic US demand for mercury in the years 1990-94 (US EPA, 1997; Maxson and Vonkeman, 1996).

Uses of mercury

108. The element mercury has been known for thousands of years, fascinating as the only liquid metal, and applied in a large number of products and processes utilising its unique characteristics. Being liquid at room temperature, being a good electrical conductor, having very high density and high surface tension, expanding/contracting uniformly over its entire liquid range in response to changes in pressure and temperature, and being toxic to micro-organisms (including pathogenic organisms) and other pests, mercury is an excellent material for many purposes.

109. In the past, a number of organic mercury compounds were used quite broadly, for example in pesticides (extensive use in seed dressing among others) and biocides in some paints, pharmaceuticals and cosmetics. While many of these uses have diminished in some parts of the world, organic mercury compounds are still used for several purposes. Some examples are the use of seed dressing with mercury compounds in some countries, use of dimethylmercury in small amounts as a reference standard for some chemical tests, and thimerosal (which contains ethylmercury) used as a preservative in some vaccines and other medical and cosmetic products since the 1930's. As the awareness of mercury's potential adverse impacts on health and the environment has been rising, the number of applications (for inorganic and organic mercury) as well as the volume of mercury used have been reduced significantly in many of the industrialised countries, particularly during the last two decades.

Examples of uses of mercury

As the metal (among others):
- for extraction of gold and silver (for centuries)
- as a catalyst for chlor-alkali production
- in manometers for measuring and controlling pressure
- in thermometers
- in electrical and electronic switches
- in fluorescent lamps
- in dental amalgam fillings

As chemical compounds (among others):
- in batteries (as a dioxide)
- biocides in paper industry, paints and on seed grain
- as antiseptics in pharmaceuticals
- laboratory analyses reactants
- catalysts
- pigments and dyes (may be historical)
- detergents (may be historical)
- explosives (may be historical)

110. However, many of the uses discontinued in the OECD countries are still alive in other parts of the world. Several of these uses have been prohibited or severely restricted in a number of countries because of their adverse impacts on humans and the environment.

111. Furthermore, while there is a general understanding of mercury production and use around the world, it is crucial to gain an even better understanding of global mercury markets and flows in order to assess demand, to design appropriate pollution prevention and reduction measures, and to monitor progress towards specific objectives.

CHAPTER 8 – Prevention and control technologies and practises

112. As noted in chapter 6, the sources of releases of mercury to the biosphere can be grouped in four major categories. Two of these categories (releases due to natural mobilisation of mercury and re-mobilisation of anthropogenic mercury previously deposited in soils, sediments and water bodies) are not well understood and largely beyond human control.

113. The other two are current anthropogenic mercury releases. Reducing or eliminating these releases may require:

- Investments in controlling releases from and substituting the use of mercury-contaminated raw materials and feedstocks, the main source of mercury releases from "unintentional" uses; and
- Reducing or eliminating the use of mercury in products and processes, the main source of releases caused by the "intentional" use of mercury.

114. The specific methods for controlling mercury releases from these sources vary widely, depending upon local circumstances, but fall generally under the following four groups:

A. Reducing mercury mining and consumption of raw materials and products that generate mercury releases;

B. Substitution (or elimination) of products, processes and practices containing or using mercury with non-mercury alternatives;

C. Controlling mercury releases through end-of-pipe techniques;

D. Mercury waste management.

115. The first two of these are "preventive" measures – preventing some uses or releases of mercury from occurring at all. The latter two are "control" measures, which reduce (or delay) some releases from reaching the environment. Within these very general groupings are a large number of specific techniques and strategies for reducing mercury releases and exposures. Whether or not they are applied in different countries depends upon government and local priorities, information and education about possible risks, the legal framework, enforcement, implementation costs, perceived benefits and other factors.

A. Reducing consumption of raw materials and products that generate mercury releases

116. Reducing consumption of raw materials and products that generate mercury releases is a preventive measure that is most often targeted at mercury containing products and processes, but may also result from improved efficiencies in the use of raw materials or in the use of fuels for power generation. This group of measures could potentially include the choice of an alternative raw material such as using natural gas for power generation instead of coal, or possibly by using a coal type with special constituents (such as more chlorine), because the mercury emissions from burning this type of coal might be easier to control than other coal types.

117. Another possible approach in some regions might be the use of coal with a lower trace mercury content (mercury concentrations appear to vary considerably in some regions depending on the origin of the raw materials). However, there are some limitations and potential problems with this approach. For example, as in the case of the utility preference for low-sulfur crude oil, it is likely that some utilities might be willing to pay more for low-mercury coal, which effectively lowers the market value of all high-mercury coal, which in turn might lead to higher consumption of high-mercury coal in regions where utilities have less rigorous emission controls. Moreover, data collected recently in the US indicate that coal supplies in the US do not vary significantly in mercury content.

118. Nonetheless, such preventive measures aimed at reducing mercury emissions are generally cost-effective, except in cases where an alternative raw material is significantly more expensive or where other problems limit this approach.

B. Substitution of products and processes containing or using mercury

119. Substitution of products and processes containing or using mercury with products and processes without mercury may be one of the most powerful preventive measures for influencing the entire flow of mercury through the economy and environment. It may substantially reduce mercury in households (and reduce accidental releases, as from a broken thermometer), the environment, the waste stream, incinerator emissions and landfills. Substitutions are mostly cost-effective, especially as they are demanded by a larger and larger market. This group of measures would also include the conversion of a fossil-fueled generating plant to a non-fossil technology.

120. At the same time, it would be a mistake to assume that substitution is always a clear winner. For example, in the case of energy-efficient fluorescent lamps, as long as there are no competitive substitutes that do not contain mercury, it is generally preferable from a product-life-cycle perspective to use a mercury-containing energy-efficient lamp rather than to use a less efficient standard incandescent lamp containing no mercury, as a result of current electricity production practises.

C. Controlling mercury emissions through end-of-pipe techniques

121. Controlling mercury emissions through end-of-pipe techniques, such as exhaust gas filtering, may be especially appropriate to raw materials with trace mercury contamination, including fossil-fueled power plants, cement production (in which the lime raw material often contains trace mercury), the extraction and processing of primary raw materials such as iron and steel, ferromanganese, zinc, gold and other non-ferrous metals and the processing of secondary raw materials such as iron and steel scrap. Existing control technologies that reduce SO_2, NO_x and PM for coal-fired boilers and incinerators, while not yet widely used in many countries, also yield some level of mercury control. For coal-fired boilers, reductions range from 0 to 96 percent, depending on coal type, boiler design, and emission control equipment. On average, the lower the coal rank, the lower the mercury reductions; however, reductions may also vary within a given coal rank. Technology for additional mercury control is under development and demonstration, but is not yet commercially deployed. In the long run, control strategies that target multiple pollutants, including SO_2, NO_x, PM and mercury, may be a cost-effective approach. However, end-of-pipe control technologies, while mitigating the problem of atmospheric mercury pollution, still result in mercury wastes that are potential sources of future emissions and must be disposed of or reused in an environmentally acceptable manner.

D. Mercury waste management

122. Mercury wastes, including those residues recovered by end-of-pipe technologies, constitute a special category of mercury releases, with the potential to affect populations far from the initial source of the mercury. Mercury waste management, the fourth "control" measure mentioned above, may consist of rendering inert the mercury content of waste, followed by controlled landfill, or it may not treat the waste prior to landfill. In Sweden, the only acceptable disposal of mercury waste now consists of "final storage" of the treated waste deep underground, although some technical aspects of this method are yet to be finalised.

123. Mercury waste management has become more complex as more mercury is collected from a greater variety of sources, including gas filtering products, sludges from the chlor-alkali industry, ashes, slags, and inert mineral residues, as well as used fluorescent tubes, batteries and other products that are often not recycled. Low concentrations of mercury in waste are generally permitted in normal landfills, while some nations only allow waste with higher mercury concentrations to be deposited in landfills that are designed with enhanced release control technologies to limit mercury leaching and evaporation. The cost of acceptable disposal of mercury waste in some countries is such that many producers now investigate whether alternatives exist in which they would not have to produce and deal with mercury waste. Mercury waste management, as it is most commonly done today, in accordance with national and local

regulations, increasingly requires long-term oversight and investment. Proper management of mercury wastes is important to reduce releases to the environment, such as those that occur due to spills (i.e. from broken thermometers and manometers) or releases that occur over time due to leakage from certain uses (e.g., auto switches, dental amalgams). In addition, given that there is a market demand for mercury, collection of mercury-containing products for recycling limits the need for new mercury mining.

Emission prevention and control measures

124. A well thought-out combination of emission prevention and control measures is an effective way to achieve optimal reduction of mercury releases. If one considers some of the more important sources of anthropogenic mercury releases, one may see how prevention and control measures might be combined and applied to these sources:

- Mercury emissions from **municipal and medical waste incinerators** may be reduced by separating the small fraction of mercury containing waste before it is combusted. For example, in the USA, free household mercury waste collections have been very successful in turning up significant quantities of mercury-containing products and even jars of elemental mercury. Also, separation programmes have proved successful in the hospital sector and a number of hospitals have pledged to avoid purchasing mercury-containing products through joint industry-NGO-Government programmes. However, separation programmes are sometimes difficult or costly to implement widely, especially when dealing with the general public. In such cases a better long-term solution may be to strongly encourage the substitution of non-mercury products for those containing mercury. As a medium term solution, separation programmes may be pursued, and mercury removed from the combustion stack gases. Mercury emissions from medical and municipal waste incineration can be controlled relatively well by addition of a carbon sorbent to existing PM and SO_2 control equipment, however, control is not 100% effective and mercury-containing wastes are generated from the process;
- Mercury emissions from **utility and non-utility boilers**, especially those burning coal, may be effectively addressed through pre-combustion coal cleaning, reducing the quantities of coal consumed through increased energy efficiency, end-of-pipe measures such as stack gas cleaning and/or switching to non-coal fuel sources, if possible. Another potential approach might be the use of coal with a lower mercury content. Coal cleaning and other pre-treatment options can certainly be used for reducing mercury emissions when they are viable and cost-effective. Also, additional mercury capture may be achieved by the introduction of a sorbent prior to existing SO_2 and PM control technologies. These technologies are under development and demonstration, but are not yet commercially deployed. Also, by-products of these processes are potential sources of future emissions and must be disposed of or reused in an environmentally acceptable manner;
- Mercury emissions due to **trace contamination of raw materials or feedstocks** such as in the cement, mining and metallurgical industries may be reduced by end-of-pipe controls, and sometimes by selecting a raw material or feedstock with lower trace contamination, if possible.
- Mercury emissions during **scrap steel production**, scrap yards, shredders and secondary steel production, result primarily from convenience light and anti-lock brake system (ABS) switches in motor vehicles; therefore a solution may include effective switch removal/collection programmes;
- Mercury releases and health hazards from **artisanal gold mining** activities may be reduced by educating the miners and their families about hazards, by promoting certain techniques that are safer and that use less or no mercury and, where feasible, by putting in place facilities where the miners can take concentrated ores for the final refining process. Some countries have tried banning the use of mercury by artisanal miners, which may serve to encourage their use of central processing facilities, for example, but enforcement of such a ban can be difficult;
- Mercury releases and occupational exposures during **chlor-alkali production** may be substantially reduced through strict mercury accounting procedures, "good housekeeping" measures to keep mercury from being dispersed, properly filtering exhaust air from the facility and careful handling and proper disposal of mercury wastes. There are a number of specific prevention methods to reduce mercury emissions to the atmosphere. The US chlor-alkali industry invented the use of ultraviolet lights to reveal mercury vapour leaks from production equipment, so that they could be plugged.

Equipment is allowed to cool before it is opened, reducing mercury emissions to the atmosphere. A continuous mercury vapour analyser can be employed to detect mercury vapour leaks and to alert workers so that they can take remedial measures. The generally accepted long-term solution is to encourage the orderly phase-out of chlor-alkali production processes that require mercury, and their substitution with technologies that are mercury free;

- Mercury releases and exposures related to mercury-containing **paints, soaps, various switch applications, thermostats, thermometers, manometers, and barometers**, as well as **contact lens solutions, pharmaceuticals and cosmetics** may be reduced by substituting these products with non-mercury products;
- Mercury releases from **dental practices** may be reduced by preparing mercury amalgams more efficiently, by substituting other materials for mercury amalgams, and by installing appropriate traps in the wastewater system;
- Mercury emissions from dental amalgams during **cremation** may only be reduced by removing the amalgams before cremation, which is not a common practice, or by filtering the gaseous emissions when the practice takes place in a crematorium. Since a flue gas cleaner is an expensive control technique for a crematorium, prevention by substituting other materials for mercury amalgams during normal dental care might be a preferred approach;
- In cases of **uncontrolled disposal of mercury-containing products or wastes**, possible reductions in releases from such practises might be obtained by making these practices illegal and adequately enforcing the law, by enhancing access to hazardous waste facilities, and, over the longer term, by reducing the quantities of mercury involved through a range of measures encouraging the substitution of non-mercury products and processes.

CHAPTER 9 - Initiatives for controlling releases and limiting use and exposures

National initiatives

125. The environmental authorities in a number of countries consider mercury to be a high-priority substance with recognised adverse effects. They are aware of the potential problems caused by use and release of mercury and mercury compounds, and therefore have implemented measures to limit or prevent certain uses and releases. Types of measures that have been implemented by various countries include:

- Environmental quality standards, specifying a maximum acceptable mercury concentration for different media such as drinking water, surface waters, air and soil and for foodstuffs such as fish;
- Environmental source actions and regulations that control mercury releases into the environment, including emission limits on air and water point sources and promoting use of best available technologies and waste treatment and disposal restrictions;
- Product control actions and regulations for mercury-containing products, such as batteries, cosmetics, dental amalgams, electrical switches, laboratory chemicals, lighting, paints/pigments, pesticides, pharmaceuticals, thermometers and measuring equipment;
- Other standards, actions and programmes, such as regulations on exposures to mercury in the workplace, requirements for information and reporting on use and releases of mercury in industry, fish consumption advisories and consumer safety measures.

126. Although legislation is the key components of most national initiatives, safe management of mercury also includes efforts to reduce the volume of mercury in use by developing and introducing safer alternatives and cleaner technology, the use of subsidies to support substitution efforts and voluntary agreements with industry or users of mercury. A number of countries have through implementation of this range of measures obtained significant reductions in mercury consumption, and corresponding reductions of uses and releases.

127. The table below gives a general overview of some of the types of implemented measures of importance to management and control of mercury, as related to its production and use life-cycle and an in-

dication of their status of implementation, based on information submitted for this report. More detailed descriptions of most of these measures are provided in chapter 9 and the separate Appendix to this report.

	TYPE AND AIM OF MEASURE	STATE OF IMPLEMENTATION
Production and use phases of life cycle		
POINT SOURCES	Prevent or limit the intentional use of mercury in processes	General bans implemented in very few countries
	Prevent or limit mercury from industrial processes (such as chlor-alkali and metallurgic industry) from being released directly to the environment	Implemented in many countries, especially OECD countries
	Apply emission control technologies to limit emissions of mercury from combustion of fossil fuels and processing of mineral materials	Implemented in some OECD countries
	Prevent or limit the release of mercury from processes to the wastewater treatment system	Implemented in some OECD countries
	Prevent or limit use of obsolete technology and/or require use of best available technology to reduce or prevent mercury releases	Implemented in some countries, especially OECD countries
PRODUCTS	Prevent or limit products containing mercury from being marketed nationally	General bans implemented in a few countries only. Bans or limits on specific products are more widespread, such as batteries, lighting, clinical thermometers
	Prevent products containing mercury from being exported	Only implemented in a few countries
	Prevent or limit the use of already purchased mercury and mercury-containing products	Only implemented in a few countries
	Limit the allowable content of mercury present as impurities in high-volume materials	Only implemented in a few countries
	Limit the allowed contents of mercury in commercial foodstuffs, particularly fish, and provide guidance (based on same or other limits values) regarding consumption of contaminated fish	Implemented in some countries, especially OECD countries. WHO guidelines used by some countries.
Disposal phase of life cycle		
Prevent mercury in products and process waste from being released directly to the environment, by efficient waste collection		Implemented in many countries, especially OECD countries
Prevent mercury in products and process waste from being mixed with less hazardous waste in the general waste stream, by separate collection and treatment		Implemented in many countries, especially OECD countries
Prevent or limit mercury releases to the environment from incineration and other treatment of household waste, hazardous waste and medical waste by emission control technologies		Implemented or implementation ongoing in some countries, especially OECD countries.
Set limit values for allowable mercury contents in sewage sludge spread on agricultural land		Implemented in a number of countries
Restrict the use of solid incineration residues in road building, construction and other applications		Implemented in some OECD countries
Prevent the re-marketing of used, recycled mercury		Only implemented in a few countries

Regional and international initiatives

128. It is also apparent that because of mercury's persistence in the environment and the fact that it is transported over long distances by air and water, crossing borders and often accumulating in the food chain far from it's original point of release, a number of countries have concluded that national measures are not sufficient. There are a number of examples where countries have initiated measures at regional, sub-regional and international levels to identify common reduction goals and ensure coordinated implementation among countries in the target area.

129. Three regional, legally binding instruments exist that contain binding commitments for parties with regards to reductions on use and releases of mercury and mercury compounds:

- LRTAP Convention on Long-Range Transboundary Air Pollution and its 1998 Aarhus Protocol on Heavy Metals (for Central and Eastern Europe and Canada and the USA);
- OSPAR Convention for Protection of the Marine Environment of the North-East Atlantic; and
- Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea.

All these three instruments have successfully contributed to substantial reductions in use and releases of mercury within their target regions.

130. The regional and sub-regional cooperation is, however, not limited to legally binding agreements. Six initiatives exist at regional or sub-regional levels that inspire and promote cooperative efforts to reduce uses and releases of mercury within the target area without setting legally binding obligations on the countries/regions participating. The initiatives are: the Arctic Council Action Plan, the Canada-US Great Lakes Binational Toxics Strategy, the New England Governors/Eastern Canada Premiers Mercury Action Plan, the North American Regional Action Plan, the Nordic Environmental Action Programme and the North Sea Conferences. Important aspects of these initiatives are the discussion and agreement on concrete goals to be obtained through the cooperation, the development of strategies and work plans to obtain the set goals and the establishment of a forum to monitor and discuss progress. Although these initiatives are not binding on their participants, there is often a strong political commitment to ensure that the agreements reached within the initiative are implemented at national/regional level.

131. There are also a number of examples of national/regional initiatives being taken by the private sector in the form of voluntary commitments that can be seen as an adjunct to public sector initiatives and as having a good chance of success as they have, by definition, the support of the primary stakeholders. All these voluntary initiatives are valuable supplements to national regulatory measures and facilitate awareness raising, information exchange and the setting of reduction goals that benefit the target region.

132. At the international level, two multilateral environmental agreements (MEAs) exist that are of relevance to mercury and mercury compounds: the Basel Convention on Control of Transboundary Movements of Hazardous Wastes and their Disposal and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Chemicals and Pesticides in International Trade. These instruments regulate trade in unwanted chemicals/pesticides or hazardous wastes. However, they do not contain specific commitments to reduce uses and releases of mercury directly. The most recently negotiated agreement relevant to chemicals, the Stockholm Convention on POPs, does not cover mercury. In addition, a number of international organizations have ongoing activities addressing the adverse impacts of mercury on humans and the environment.

133. A more detailed compilation of national initiatives, including legislation, in each individual country is contained in an appendix to this report, entitled "Overview of existing and future national actions, including legislation, relevant to mercury". The Appendix is published in a separate document. The information compiled therein has been extracted from the national submissions received from countries under this project.

CHAPTER 10 – Data gaps

National research and information needs

134. A number of countries have in their submissions to UNEP expressed a need for establishing or improving their national "database" (i.e. knowledge of and information on uses and emissions, sources of releases, levels in the environment and prevention and control options) on mercury and mercury compounds. Although the situation varies from country to country, there seems to be a general need for information relevant to the various elements of an environmental management strategy for mercury. Also, countries with a longer tradition of environmental management of mercury have expressed the need to continue to expand their knowledge base on mercury to improve risk assessment and ensure effective risk management. Some of the needs include, among others:

- Inventories of national use, consumption and environmental releases of mercury;
- Monitoring of current levels of mercury in various media (such as air, air deposition, surface water) and biota (such as fish, wildlife and humans) and assessment of the impacts of mercury on humans and ecosystems, including impacts from cumulative exposures to different mercury forms;
- Information on transport, transformation, cycling, and fate of mercury in various compartments;
- Data and evaluation tools for human and ecological risk assessments;
- Knowledge and information on possible prevention and reduction measures relevant to the national situation;
- Public awareness-raising on the potential adverse impacts of mercury and proper handling and waste management practises;
- Appropriate tools and facilities for accessing existing information relevant to mercury and mercury compounds at national, regional and international levels;
- Capacity building and physical infrastructure for safe management of hazardous substances, including mercury and mercury compounds, as well as training of personnel handling such hazardous substances.
- Information on the commerce and trade of mercury and mercury-containing materials.

135. In principle, some parts of this information might be exchanged nationally, regionally or internationally, as its relevance is often universal, however, it might need to be "translated" into the context of the individual country's framework of traditions, economic and industrial activities and political reality. This, in itself, demands a substantial degree of priority, knowledge and funding. Other parts of the information are country specific and would require national efforts to research, collect and process the information.

Data gaps of a general, global character

136. Although mercury is probably among the best-studied environmental toxicants, there are data gaps in the basic understanding of a number of general, global issues relevant to mercury. Based on submitted information and the compilation and evaluation hereof, a possible division of current data gaps of global relevance on mercury could be as follows (not in order of priority):

- Understanding and quantification of the **natural mechanisms affecting the fate of mercury** in the environment, such as mobilisation, transformation, transports and intake. In other words, the pathways of mercury in the environment, and from the environment to humans.
- Understanding and quantification – in a global perspective – of the **human conduct in relation to mercury releases**, and the resulting human contributions to the local, regional and global mercury burden. In other words, the pathways of mercury from humans to the environment.
- Understanding of how and to what degree humans, ecosystems and wildlife are **adversely affected by the current mercury levels** found in the local, regional and global environment. In other words, the possible effects, number affected, and the magnitude and severeness in those affected.

137. A basic understanding has been established for all three categories mentioned above, based on about half a century's extensive research on the impacts and pathways of mercury. However, in a number of areas, further research is needed to provide new information to improve environmental modelling assessments and modern decision-making tools. Despite these gaps in information, a sufficient understanding has been developed of mercury (including knowledge of its fate and transport, health and environmental impacts, and the role of human activity) that international action to address the global adverse impacts of mercury should not be delayed.

CHAPTER 11 – Options for addressing any significant global adverse impacts of mercury

138. The UNEP Governing Council requested, as part of the global assessment on mercury, an outline of options for consideration by the Governing Council, addressing any significant global adverse impacts of mercury, inter alia, by reducing and or eliminating the use, emissions, discharges and losses of mercury and its compounds; improving international cooperation; and ways to enhance risk communication.

139. As part of the implementation of Governing Council decision 21/5, UNEP established a Working Group to assist it in preparing for the Governing Council's discussions on the issue at its session in February 2003. The Global Mercury Assessment Working Group, at its first meeting held from 9 to 13 September 2002, finalized this assessment report for presentation to the Governing Council at its 22nd session. At this meeting, the Working Group arrived at a number of conclusions of relevance to the Governing Council's considerations:

- Based on the key finding of this report, the Working Group concluded that, in its view, there was sufficient evidence of significant global adverse impacts to warrant international action to reduce the risks to human health and/or the environment arising from the release of mercury into the environment. While it was important to have a better understanding of the issue, the Working Group emphasized that it was not necessary to have full consensus or complete evidence in order to take action and therefore potentially significant global adverse impacts should also be addressed.

- The Working Group also agreed on an outline of options for recommendation on measures to address global adverse impacts of mercury at the global, regional, national and local levels. The options include measures such as reducing or eliminating the production, consumption and releases of mercury, substituting other products and processes, launching negotiations for a legally-binding treaty, establishing a non-binding global programme of action, and strengthening cooperation amongst governments on information-sharing, risk communication, assessment and related activities.

- Finally, the Working Group agreed to the need to submit to the Governing Council a range of possible immediate actions in light of their findings on the impacts of mercury, such as increasing protection of sensitive populations (through enhanced outreach to pregnant women and women planning to become pregnant), providing technical and financial support to developing countries and to countries with economies in transition, and supporting increased research, monitoring and data-collection on the health and environmental aspects of mercury and on environmentally friendly alternatives to mercury.