ZERO MERCURY CAMPAIGN – FACTBOOK

Executive Summary

Contents

CHAPTER 1 INTRODUCTION

- Mercury occurs naturally in the environment and exists in a large number of forms. Mercury is best known in its elemental form as a shiny, silver-white metal that is a liquid at room temperature. 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 (UNEP 2002).

- Mercury is a heavy metal and a constituent element of the earth. with an average abundance of approximately 0.05 mg/kg in the earth's crust, with significant local variations. 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 (UNEP 2002).

- 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 (UNEP 2002).

- Appendix 1: Properties of Mercury

1.1 Forms of Mercury (Elemental, Inorganic, Organic)

- The chemical form of mercury (or speciation) released varies depending on the source types and other factors. This also influences the impacts on human health and other living organisms environment as different mercury species have different toxicity (UNEP 2002).

- Among other things, the species influence:

  - The transport of mercury within and between environmental compartments including the atmosphere and oceans, among others.

- 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 (UNEP 2002)

1.1.1 Elemental Form (metallic, Hg^0)

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

- 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 (UNEP 2002).

1.1.2 Inorganic Forms (Hg^+, Hg^{2+})

- 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) (UNEP 2002).

- 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 significantly shorter atmospheric lifetimes for these divalent mercury gases than for the elemental mercury gas (UNEP 2002).

1.1.3 Organic Forms

- When mercury combines with carbon, the compounds formed are called "organic" mercury compounds or organo-mercurials. 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 that micro-organisms and natural processes generate in the environment is **methylmercury** (UNEP 2002).

- Methylation is a product of complex processes that move and transform mercury (USGS 2000).

- 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 (UNEP 2002).

- 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 (UNEP 2002).

- 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 (UNEP 2002).

1.2 Natural versus Anthropogenic Sources

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

  a) Natural sources - releases due to natural mobilisation of naturally occurring mercury from the Earth's crust, such as volcanic activity and weathering of rocks;

  b) Current anthropogenic (associated with human activity) releases from mercury used intentionally in products and processes, due to releases during manufacturing, leaks, disposal or incineration of spent products or other releases, 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;

  c) Re-mobilisation of historic anthropogenic mercury releases previously deposited in soils, sediments, water bodies, landfills and waste/tailings piles. (UNEP 2002)

- 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 (UNEP 2002).

- 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 (UNEP 2002).

- 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 (UNEP 2002).

1.2.1 <u>Natural Sources</u>

- Several forms of mercury occur naturally in the environment. The most common natural forms of mercury found in the environment are metallic mercury, inorganic mercuric salts (i.e. mercuric sulphide (HgS), mercuric chloride ($HgCl_2$) and mercuric oxide (HgO)), and the organic mercuric compound methylmercury (UNEP 2002)

- Natural sources of atmospheric mercury include volcanoes, geologic deposits of mercury, and volatilization from the ocean, evaporation from soil and water surfaces. Although all rocks, sediments, water, and soils naturally contain small but varying amounts of mercury, scientists have found some local mineral occurrences and thermal springs that are naturally high in mercury (USGS 2000).

- 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.

- 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.

- In addition to emissions from natural sources 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 and makes it very difficult to determine the actual natural mercury emissions (UNEP 2002).

1.2.2 <u>Anthropogenic Sources</u>

- 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 (e.g. petroleum products)
- Cement production (mercury in lime)
- Forest fires
- Evaporation from oceans
- 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 (i.e. inorganic mercury waste)
- Photographic processing

- 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)
- Paper pulp factories (i.e. slimicides)
- Industrial run-off, seepages and discharges
- Landfills
- Cremation
- Cemeteries (release to soil) (Clarkson 2002, UNEP 2002, DEH 2004)

- 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 (UNEP 2002).

- 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 (UNEP 2002).

- 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 1000km. However, significant conversion between mercury species may occur during atmospheric transport, which will affect the transport distance (UNEP 2002).

- 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 (UNEP 2002).

1.3 Atmosphere

- Alkali and metal processing, burning of fossil fuel, incineration of medical and other waste, and mining of gold and mercury contribute greatly to mercury concentrations in some areas, but atmospheric deposition is the dominant source of mercury over most of the landscape (USGS 2000).

- Mercury vapor is a chemically stable monatomic gas. Once in the atmosphere, mercury is widely disseminated (USGS 2000). 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 (UNEP 2002). By processes not yet fully understood, mercury vapor is oxidized in the upper atmosphere to a water-soluble ionic mercury, which is returned to the earth's surface in rainwater. This global cycling of mercury results in the distribution of mercury to the most remote regions of the planet (Clarkson 2002).

- Atmospheric deposition contains the three principal forms of mercury, although inorganic divalent mercury (HgII) is the dominant form. Once in surface water, mercury enters a complex cycle in which one form can be converted to another (USGS 2000)

- 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 (UNEP 2002)

- 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). (UNEP 2002).

- Exposure of methylmercury to sunlight (specifically ultra-violet light) has an overall detoxifying effect. Sunlight can break down methylmercury to Hg(II) or Hg(0), which can leave the aquatic environment and re-enter the atmosphere as a gas (USGS 2000).

- 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 (UNEP 2002).

CHAPTER 2 MERCURY DATA & STATISTICS

2.1 Global Mercury Situation

- 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 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 (UNEP 2002).

- Mercury is naturally present in coal and other fossil fuels, as well as in minerals like lime for cement production and soils (such as agricultural soils subject to acidification management) and metal ores including for example zinc-, copper- and gold ore. Coal-fired power production is today deemed the single largest global source of atmospheric mercury emissions (Pacyna and Pacyna, 2000). This is due to the increasing global power consumption, and also to the fact that emissions from intentional use of mercury are gradually diminishing in many of the industrialised countries (UNEP 2002).

Top Ten Hard Coal Producers (2004e)

PR China	1956 Mt	Russia	210 Mt
USA	933 Mt	Indonesia	129 Mt
India	373 Mt	Poland	100 Mt
Australia	285 Mt	Kazakhstan	83 Mt
South Africa	238 Mt	Ukraine	62 Mt

Global Hard Coal Consumption

	1984	1994	2004e
World	3066 Mt	3541 Mt	4646 Mt
Selected Regional Aggregate Estimates			
Europe	17%	12%	8%
FSU	18%	10%	6%
N. America	22%	23%	21%
Asia-Pacific	38%	50%	60%

- Over 66% of total global steel production relies on inputs of coal (WCI 2005b).

- Crude Steel Production

1994	1996	1999	2001	2002	2003	2004
725.1 Mt	750.0 Mt	789.0 Mt	850.2 Mt	903.8 Mt	968.3 Mt	est. 1000 Mt

Major Producers of Steel

PR China	220.1 Mt	Germany	44.8 Mt
Japan	110.5 Mt	Ukraine	36.9 Mt
USA	93.7 Mt	India	31.8 Mt
Russia	62.7 Mt	Brazil	31.2 Mt
South Korea	46.3 Mt	Italy	26.8 Mt

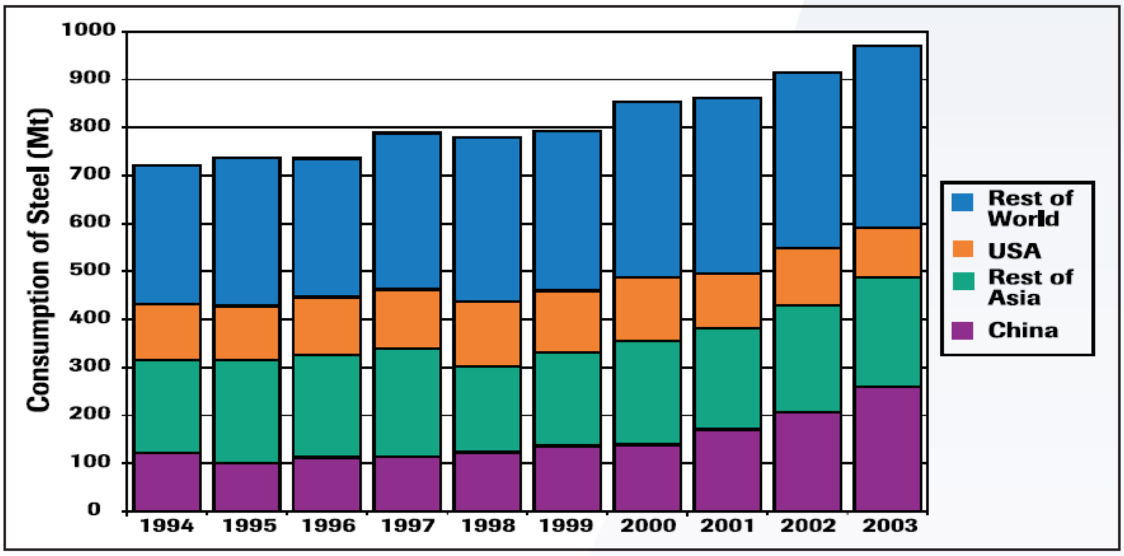
Steel production in China increased by 73% between 2000 and 2003 – China accounts for around 23% of global steel production (WCI 2005b).

- Some 970 Mt of crude steel were consumed worldwide in 2003, compared with 915 Mt in 2002 (WCI 2005b).

- Major Consumers of Crude Steel

PR China	258.2 Mt	USA	103.9 Mt	Japan	77.0 Mt

South Korea 47.2 Mt Germany 37.5 Mt Italy 33.6 Mt



(WCI 2005b)

- 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 1 -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.

(UNEP 2002)

2.1.1 Sources of mercury to the market

- 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 (UNEP 2002).

Continued mining of primary mercury

- 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

Large supplies of recycled mercury may be marketed

- 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.

2.2 PRC's Mercury Situation

- Coal is one of the country's most abundant resources and the cheapest and most convenient to use but also the world's dirtiest source of energy that powers nearly 70% of Chinese industry (Schmidt 2002) but also the cheapest (WHO 2001).

- Coal combustion continues to be the major source of air pollution in the whole country (WHO 2001).

- Despite recent improvements, 9 of the 10 cities with the world's worst air pollution are found in China, and respiratory diseases linked to poor air are the leading cause of death among both children and adults, according to a November 1999 report by the World Resources Institute, *Urban Air Pollution Risks to Children: A Global Environmental Health Indicator* (Schmidt 2002).

- China emits approximately 495 tons of mercury annually from power plants and other sources. It is expected to increase emissions over the next two to five years by 20 - 30 tons annually due to its rapid economic growth and industrial expansion. The projected annual growth in China's mercury emissions alone is more than half of the current U.S. power plant emissions in total (Pombo & Gibbons 2005).

- China reports the following regarding the emissions of mercury from coal combustion in the country: According to information from research, the average mercury content of coal is 0.038 – 0.32 mg/kg. The total amount of mercury emissions from coal combustion was about 296-302.9 metric tons annually in the middle of the 1990's, including 213.8 metric tons in the atmosphere and 89.07 metric tons in ash and cinder. The average content of organic mercury in coals collected from 15 provinces and cities was 0.037 mg/kg, occupying 18.1 percent of the mercury. The average contents of organic mercury in fly ashes of burning coal 0.045 mg/kg, occupying 28.1 percent of total mercury in ash. From 1978 through 1995, mercury emission had been increasing at average 4.8 percent per year." (Comments from China, comm-19-gov) (UNEP 2002).

- The reserve of coal is about 860 billion tons. In 1996, China produced a total of 1.4 billion tons of raw coal. Coal accounts for more than 75 % of China's total consumption of primary energy, compared with 17 % in Japan and a world average of 27 % (WHO 2001).

- There are several kinds of coal, such as blind coal, soft coal, and coking plant soft coal. However, the quality of coal in China is poor, especially the southwestern part. Coal has about 25% ash with an average value of 17.6%. Coal with high sulphur is mainly distributed in the southwest part of China, such as Sichuan, Chongqing and Guizhou, with maximum sulphur content of about 6.26%, 4% and 4.6%, respectively (WHO 2001).

- In 1998, the industrial and residential coal consumption per km2 in northern China was largest among the seven regions. However, the region with highest residential coal consumption per household has been the southwest part. Industries account for two-thirds of total coal use; industrial boilers alone consume 30%. These boilers are usually inefficient and emit fine particulates and SO2 through low smoke stacks. Industries with dirty boilers are located in densely populated metropolitan areas, placing communities in these areas at high risk of exposure (WHO 2001).

- In general terms about 74% of the Chinese population live in areas where the air quality does not meet the standard (Report on the state of the Environment in China 2002. State Environmental Protection Agency 2003). In addition to the ambient atmospheric environment many people especially women will be exposed to air contamination inside their households (WHO 2001).

- The data on coal consumption per household in each of the provinces has also been shown to correlate significantly with the mortality rates of chronic obstructive pulmonary diseases (COPD), lung cancer, and lead poisoning, indicative of the health risks of indoor pollution due to cooking and heating purposes. The association between air pollution and disease is not easy to establish (WHO 2001).

2.2.1 Chlor-alkali production and residual mercury

- Qi *et al*. (2000) reported that mercury releases (including mercury in wastes from Chinese chlor-alkali plants decreased significantly from 500-1400 g of mercury/ton of sodium hydroxide production before 1977, to 160-180 g of mercury/ton of sodium hydroxide production in 1997, but were still much higher than in some other countries. Specifically, these 1997 Chinese releases were more than 4 times greater per ton of production, than OSPAR releases (including mercury wastes, which were stored or treated according to relevant legislation) at that time. However, most chlor-alkali plants in China use the diaphragm process, which does not use mercury, and there are plans for converting or closing the few remaining mercury-cell chloralkali facilities in China (we know of only one, owned by the Tianjin Chemical Company, with a capacity of 50 thousand metric tons chlorine per year) (UNEP 2002).

2.2.2 Artisanal Mining

- China's mercury mining industry is almost exclusively concentrated in southwestern China, primarily in Guizhou Province. During the 1990s, China's mercury production varied from roughly 500 to 800 tonnes per year (Gunson and Veiga 2004).

- In China, over 200 small mines were said to have been opened since 1992 in one province after permission to form individual enterprises was granted. This induced an increment in gold production of 10 percent, according to Yshuan (personal communication, in Lacerda, 1997a). This may be one explanation for the relatively high mercury imports to China pointed out by Sznopek and Goonan (2000), and Scoullos *et al.* (2000). During the last couple of years, however, all artisanal mining of gold (and mercury) has been forbidden by the Chinese authorities (UNEP 2002).

CHAPTER 3 ECOLOGICAL EFFECTS

Background

- 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 (USGS 2000).

- Inorganic mercury can also be absorbed, but is generally taken up at a slower rate and with lower efficiency than is methylmercury (UNEP 2002).

- The exact mechanisms by which mercury enters the food chain remain largely unknown and may vary among ecosystems. Certain bacteria play an important early role. Bacteria that process sulfate (SO_4=) in the environment take up mercury in its inorganic form and convert it to methylmercury through metabolic processes. The conversion of inorganic mercury to methylmercury is important because its toxicity is greater and because organisms require considerably longer to eliminate methylmercury. This is the first step in the aquatic food chain. These methylmercury-containing bacteria may be consumed by the next higher level in the food chain, or the bacteria may excrete the methylmercury to the water where it can quickly adsorb to plankton, which are also consumed by the next level in the food chain. Because animals accumulate methylmercury faster than they eliminate it, animals consume higher concentrations of mercury at each successive level of the food chain. Small environmental concentrations of methylmercury can thus readily accumulate to potentially harmful concentrations in fish (e.g. pike, bass), fish-eating wildlife (e.g. otters) and people. Even at very low atmospheric deposition rates in locations remote from point sources, mercury biomagnification can result in toxic effects in consumers at the top of these aquatic food chains." (USGS 2000, Clarkson 2002)

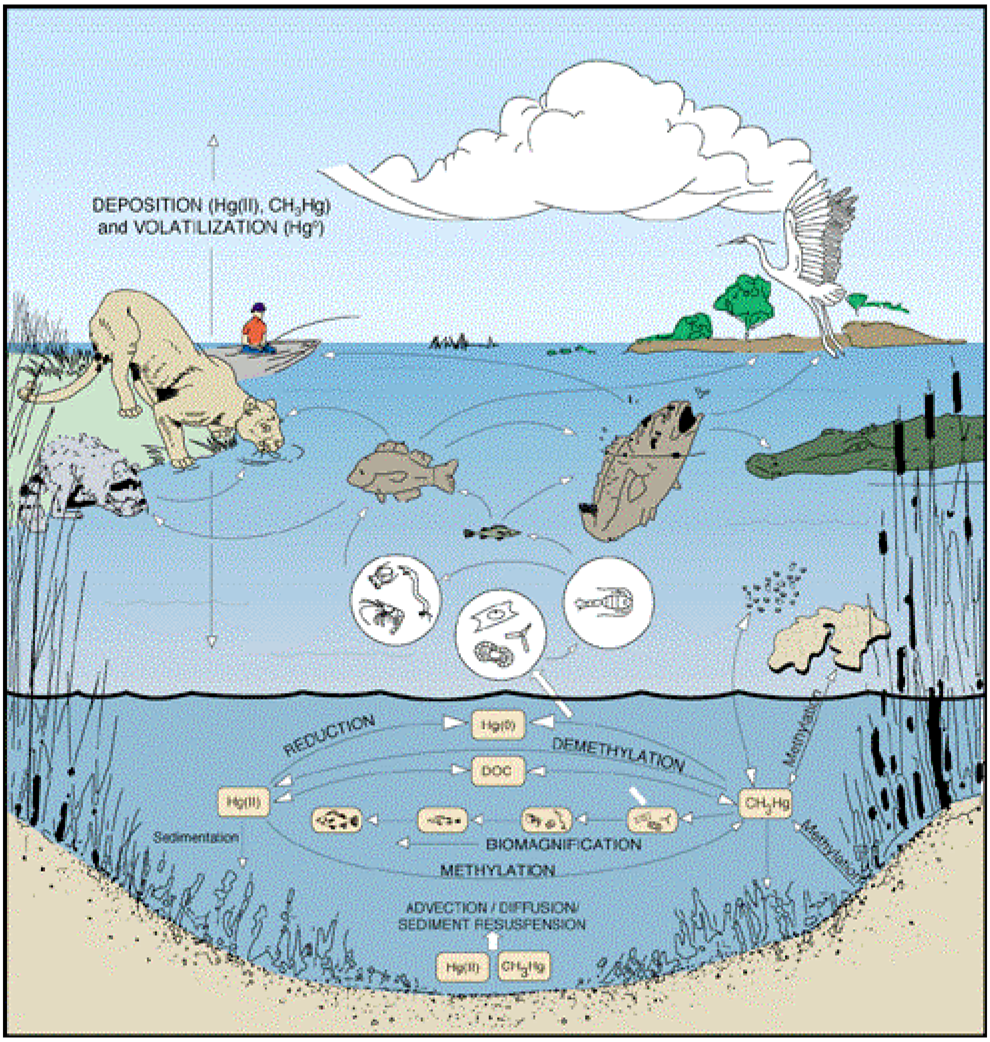
- The mercury concentrations are lowest in the smaller, non-predatory fish and can increase many-fold on the way up the food chain. Aquatic food webs tend to have more levels than terrestrial webs, where wildlife predators rarely feed on each other, and therefore the aquatic biomagnification typically reaches higher values (UNEP 2002). 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. 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 (UNEP 2002).

- 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, which have been found in a study to have higher tissue levels of mercury (US EPA, 1997).

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).



(USGS 2000)

- 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 (UNEP 2002).

- Methyl mercury was soon detected in all species of fish and in fish-consuming animals. The source appeared to be inorganic mercury biomethylated by microorganisms in sediments of both fresh and ocean water (Clarkson 2002).

- 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 (UNEP 2002).

- It only takes about one gram (the mercury content of 87, 4-foot fluorescent lamps of the typical content of a mercury thermometer) of airborne mercury deposited each year into a 25-acre lake to contaminate the fish to a level that is unsafe to eat (National Wildlife Federation 2000, HCWH 2002a).

- Historically, the use of organic mercury compounds for agricultural seed dressing has resulted in mercury exposures of seed-eaters, particularly birds and rodents (Fimreite, 1970; Johnels *et al*., 1979, in Pirrone *et al*., 2001). Where the use of mercury-coated seeds continues, some impact on the terrestrial environment is expected (UNEP 2002).

- 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) (UNEP 2002).

- Recent evidence suggests that mercury is responsible for a reduction of microbiological 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.

- Once in the atmosphere, mercury can be transported across the globe and can deposit into lakes and streams via precipitation or dry deposition (National Wildlife Federation 2000). 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.

- Very small amounts of mercury can do significant damage. One gram of mercury is enough to contaminate all the fish in a lake with a surface area of 20 acres. A typical mercury thermometer contains approximately 0.7 grams of mercury (700 milligrams), but larger thermometers can contain as much as three grams. Both short term and long term exposure to mercury can cause serious health problems for humans and wildlife (HCWH 2002c)

FACTORS

- In highly polluted areas where mercury has accumulated through industrial or mining activities, natural processes may bury, dilute, or erode the mercury deposits, resulting in declines in concentration. In many relatively pristine areas, however, mercury concentrations have actually increased because atmospheric deposition has increased (USGS 2000).

- 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.

- Lake acidification, addition of substances like sulfur that stimulate methylation, and mobilization of mercury in soils in newly flooded reservoirs or constructed wetlands have been shown to increase the likelihood that mercury will become a problem in fish." (USGS 2000).

- The concentration of dissolved organic carbon (DOC) and pH have a strong effect on the ultimate fate of mercury in an ecosystem. Higher acidity and DOC levels enhance the mobility of mercury in the environment, thus making it more likely to enter the food chain (USGS 2000).

SOIL

- Soil conditions are typically favourable for the formation of inorganic and organic compounds, which form complexes with organic anions. This complexing behaviour controls to a large extent the mobility of mercury in soil. Much of the mercury in soil is bound to bulk organic matter and is susceptible to wash out in runoff only when attached to suspended soil or humus (UNEP 2002).

- Until recently, inorganic mercury was not considered a major source of effects in the soil compartment because it is bound to the soil particles and is not very bioavailable to plants or organisms. In fact, the uptake of gaseous elemental mercury through leaves is much more efficient than the uptake of soil mercury (Hg(II)) in roots, and the main exposure of plants may therefore be through the air (UNEP 2002).

- Therefore, mercury has a long retention time in soil and as a result, the mercury accumulated in soil may continue to be released to surface waters and other media for long periods of time, possibly hundreds years (Pirrone *et al*., 2001) (UNEP 2002).

- 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 (UNEP 2002).

3.1 Case-Studies

- According to a three-year study (1996-1998) by The Open University in Hong Kong, tests of water samples from the East River - the source of 80 percent of the SAR's drinking water - found the levels of heavy metals are much higher than international safety standards. Water quality in the East River has been worsening due to increasing urbanisation in southern Guangdong (Mineralysis 2002).

- Severe neurological effects was seen in birds in Minamata, Japan, from about 1950-1952 (prior to the recognition of human poisonings), which experienced severe difficulties in flying, and exhibited other grossly abnormal behaviour (US EPA, 1997). Signs of neurological disease were also observed among domestic animals (especially cats whose diets were high in seafood, included convulsions, fits, highly erratic movements (mad running, sudden jumping, bumping into objects) (UNEP 2002).

CHAPTER 4 HEALTH EFFECTS

Background

- Appendix 2: Material Safety Data Sheet (MSDS) for Mercury

- Mercury is a widespread heavy metal whose toxic effects have been well documented (Mineralysis 2002).

- The health effects of mercury exposure depend on its chemical form (elemental, inorganic or organic), the route of exposure (inhalation, ingestion or skin contact), and the level of exposure. Vapour from liquid elemental mercury and methyl mercury are more easily absorbed than inorganic mercury salts and can, therefore, cause more harm. You should try to reduce your exposure to all forms of mercury whenever possible (Health Canada 2004).

- All three forms are toxic in different ways (Mineralysis 2002). 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) (UNEP 2002).

- Mercury will enter the body if we breathe in contaminated air, drink contaminated water, eat contaminated food, or have our skin come into contact with it (i.e. inhalation, ingestion or dermal absorption). Mercury may be absorbed through the skin (DEH 2004, Ingham County 2005).

4.1 Mercury Sources

- Sources of Mercury

- Deteriorating Mercury Amalgams	- Cosmetics (some)	- Fungicides (some)
- Bleaching Skin Creams (some)	- Medications (some)	- Polluted Water
- Diuretics (some)	- Battery Manufacturing	- Cooking and home heating*
- Petrol	- Contaminated Seafood**	

* Prevalent in most part of the country

** Even more toxic is dried delicacies, like shark's fin, scallop (added to many Cantonese dishes), squid and oyster. (30 times more mercury than fresh fish) (Mineralysis 2002, DEH 2004)

- Indoor air mercury levels can also become elevated due to leaks from central-heating thermostats and by the use of vacuum cleaners after thermometer breakage and other spills. Another source of exposure to mercury vapor has been the release of mercury from paint containing mercury compounds used to prolong shelf-life of interior latex paint, in which levels of 0.3-1.5 µg Hg/m3 (Beusterien *et al.*, 1991) have been reported. However, as explained in other sections of this report, the use of mercury in paints has decreased substantially in many nations of the world, therefore this source of exposure may be less common today than it was 10-30 years ago (UNEP 2002).

- Mercury can be absorbed through the skin. Workers in the industries that use or produce mercury and its compounds (mercury mines and refineries, chemical manufacturing, dental/health fields, metal smelters) are at risk of exposure. Workers in fossil fuel power plants and in cement manufacturing may be exposed to mercury compounds if they are exposed to gaseous process emissions. Consumers can be exposed to mercury and its compounds by exposure to air from production and processing facilities using mercury and its compounds, by eating fish or shellfish contaminated with methyl mercury. People can also be exposed to mercury from dental work and medical treatments (DEH 2004).

How much mercury causes poisoning?

- Mercury causes poisoning only after it reaches a certain level in the body. The toxicity depends on the amount of mercury consumed in relation to body weight. Therefore, for a fixed amount of exposure to mercury, infants are at greater risk than adults. Different expert bodies have determined that safe levels of mercury consumption lie somewhere between 0.7 to 3.3 micrograms of mercury per kilogram of body weight per week. The US Environmental Protection Authority (EPA) has set the lowest cut-off point at 0.7 micrograms of mercury per kilogram of body weight per week, and the World Health Organization (WHO) has suggested 3.3 micrograms per kilogram of body weight per week. These levels are considered to be as much as ten times below the upper safety margin (Immunise Australia Program 2002).

- The U.S. EPA-recommended safe intake level is referred to as the reference dose and is defined as that dose that can be absorbed daily for a lifetime without a significant risk of adverse effects. The new reference dose was estimated in 1997 to be **0.1μg methylmercury/kg body weight/day**. This dose implies that the amount of methyl mercury ingested in just one 7-oz can of tuna fish per week would equal or even slightly exceed the new limit, depending on the consumer's body weight. Other federal regulatory agency guidelines allow higher levels (National Research Council. Toxicological Effects of Methylmercury. Washington, DC:National Academy Press, 2000): The U.S. Food and Drug Administration (FDA) guideline is equivalent to 0.5 μg Hg/kg/day, and that of the Agency for Toxic Substances and Disease Registry (ATSDR) is 0.3 μg Hg/kg/day (Clarkson 2002).

- The amount of mercury absorbed by the body -and thus the degree of toxicity - is dependent upon the chemical form of mercury. For instance, ingested elemental mercury is only 0.01% absorbed, but methyl mercury is nearly 100% absorbed from the gastrointestinal tract. The biological half-life of mercury is 60 days. Thus, even though exposure is reduced, the body burden will remain for at least a few months. Elemental mercury is most hazardous when inhaled. Only about 25% of an inhaled dose is exhaled. Skin absorption of mercury vapor occurs, but at low levels (ex. 2.2% of the total dose). Dermal contact with liquid mercury can significantly increase biological levels. The primary focus of this article is elemental mercury, since that is the form of exposure to health care workers involved with mercury-containing instrument accidents (Ingham County 2005).

<u>Elemental</u>

- The health effects of **elemental mercury** depend on the length and type of exposure. For example, if you were to accidentally swallow liquid elemental mercury from a broken fever thermometer, little mercury would be absorbed. If elemental mercury is ingested, it is absorbed relatively slowly and may pass through the digestive system without causing damage (USGS 2000).

- 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. (UNEP 2002). However, if you were to inhale the vapour from that mercury spill, it would be more easily absorbed into your body, potentially causing health problems. At higher concentrations, mercury vapour can cause damage to the mouth, respiratory tract and lungs, and can lead to death from respiratory failure. Long-term exposure to low concentrations causes symptoms similar to those of methyl mercury (Health Canada 2004).

- Elemental mercury is absorbed as vapour and is highly toxic. Mercury readily vaporises even at room temperature and exposure to it can lead to damage in the central nervous system, neurological and behavioural disorders in humans (Mineralysis 2002, UNEP 2002). Intestinal absorption of elemental mercury is low. However, it will contaminate the environment when it enters the waste water system (HCWH 2002b).

- Elemental mercury can be oxidized in body tissues to the inorganic divalent form (UNEP 2002)

- Elemental mercury, the form released from broken thermometers, fluorescent tubes and batteries causes tremors, gingivitis, and excitability when vapors are inhaled over a long period of time (Mineralysis 2002).

- 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. (UNEP 2002).

- When a mercury thermometer breaks, the liquid silver-colored metal can spill onto the floor or carpet. Breaking one fever thermometer is unlikely to threaten the health of the consumer if the spilled mercury is cleaned up properly. However, if the consumer fails to clean up mercury either because he or she is unaware that it has broken or because it is difficult to gain access to the mercury (for instance because it has seeped through a carpet), then the mercury will eventually evaporate into the air and reach dangerous levels in indoor air. The risks increase if the consumer attempts to clean up a mercury spill with a vacuum cleaner, or if the mercury is heated. The danger of significant mercury exposure is greatest in a small, poorly ventilated room (HCWH 2002b).

Inorganic

- Ingestion of other common forms of mercury, such as mercury salts (e.g. $HgCl_2$) and some dermatological preparations is unlikely from environmental sources (USGS 2000).

- Inorganic mercury can cause kidney failure and gastrointestinal damage. Mercury salts are irritating, and can cause blisters and ulcers on the lips and tongue. Rashes, excessive sweating, irritability, muscle twitching, weakness and high blood pressure are other symptoms of elevated exposures (Health Canada 2004).

- Inorganic mercury cannot cross the blood-brain barrier but reaches the kidney, and it is this organ particularly that is damaged (Mineralysis 2002).

- 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 (UNEP 2002).

Organic

- Organic mercury compounds (R-Hg+) derived from fish, seafood, fungicides, herbicides, and wood preservatives are readily absorbed by living organisms and are considered more hazardous than inorganic mercury (Mineralysis 2002).

- 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 (UNEP 2002).

- For alkylmercury compounds, among which methylmercury is by far the most important, the major source of exposure is diet, especially fish and other seafood (UNEP 2002). The methyl mercury will build up in the tissues of fish and shellfish but especially in predatory fish, which may cause poisoning when consumed by humans (and other animals) (DEH 2004).

- 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 <u>how</u> 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 (UNEP 2002).

- To put the level of exposures for methylmercury in perspective, for the most widely accepted non-lethal adverse effect (neurodevelopmental effects), the United States National Research Council estimated the benchmark dose (BMD) to be 5.8μg/L total mercury in cord blood (or 10μg/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) (UNEP 2002)

- The maximum safe, weekly recommended intake levels of mercury is 1.6 μg per kg body weight (international standards) or 0.7 μg per kg body weight (US-NRC standards) (Farrar-Hockley 2005)

- 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 (UNEP 2002).

- Mercury can change from one form to another in the environment. Exposure to methylmercury is usually by ingestion; it is absorbed through the intestines and distributed throughout the body. It readily enters the brain, where it may remain for a long period of time. In a pregnant woman, it can also cross the placenta into the fetus, building up in the fetal brain and other tissues (Health Canada 2004). This is particularly damaging to developing embryos, which are 5 – 10 times more sensitive than adults (USGS 2000). Methyl mercury can also be passed to the infant through breast milk (Health Canada 2004).

- A study by the World Health Organisation (WHO) in 1995 showed that a major source of mercury accumulation in the human body comes from food. Concentrations of mercury in meat can be as high as those in fish and seafood but because meat stores inorganic mercury, only 10 percent of it stays in the body. Fish and seafood retain methylmercury, of which up to 90 per cent can be stored in the body's tissues.

- Methylmercury is absorbed more readily and excreted more slowly than other forms of mercury (USGS 2000)

- As mercury is naturally occurring and is ubiquitous in the environment, we are all exposed to it at low levels. The degree of exposure depends on the methylmercury concentrations found in the seafood consumed and the amount consumed. Generally, our bodies eliminate this trace amount of mercury over a period of 1 to 3 months (Pombo & Gibbons 2005).

- It is important to remember that the body can and does get rid of mercury over time. So people only go over the safe levels if they eat a lot of high mercury fish regularly over many months (DHS 2004).

FISH

- 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 (UNEP 2002).

- Consumption of fish or long chain omega-3 polyunsaturated acids benefits all people from pre-term infants to older adults. Regular fish consumption has beneficial health effects for people with heart disease and various types of cancer, including breast, prostate and endometrial. In addition, fish consumption has beneficial impacts on people suffering from Alzheimer’s disease and type 2-diabetes and can reduce the risk of heart attack, contribute to infant eye and brain development, lessen the symptoms of rheumatoid arthritis and may slow the progression of breast and other forms of cancer (Pombo & Gibbons 2005).

- Misinformation has effectively reduced or even eliminated fish from the diets of women of childbearing age out of fear of harming their unborn children. Fish is known to be an important source of protein, omega-3 polyunsaturated acids and other important nutrients. A balanced diet that includes fish is known to significantly reduce the risks of pre-term delivery and low birth weight, and is known to have positive impacts on physiological and mental development in children (Pombo & Gibbons 2005).

- People are exposed to methylmercury almost entirely by eating contaminated fish and wildlife that are at the top of aquatic foodchains. The National Research Council, in its 2000 report on the toxicological effects of methylmercury, pointed out that the population at highest risk is the offspring of women who consume large amounts of fish and seafood. The report went on to estimate that more than 60,000 children are born each year at risk for adverse neuro-developmental effects due to in utero exposure to methylmercury. In its 1997 Mercury Study Report to Congress, the U.S. Environmental Protection Agency concluded that mercury also may pose a risk to some adults and wildlife populations that consume large amounts of fish that is contaminated by mercury (USGS 2000).

- Concentrations of mercury in most foodstuffs are often below the detection limit (usually 20 ng Hg per gram fresh weight) (US EPA 1997). Fish and marine mammals are the dominant sources, mainly in the form of methylmercury compounds, making up70-90 percent or more of the total mercury content. Some fish contain more mercury than others. The normal mercury concentrations in edible tissues of various species of fish cover a wide range, generally from 0.05 to 1.400 mg/kg fresh wet weight depending on factors such as pH and redox potential of the water, species, age, location, habitat, diet and size of the fish. Fish that are predatory (eat other fish) are large and at the top of the food chain, and so tend to contain more mercury (US EPA 2001a, DHS 2004); for example, king mackeral, pike, shark, swordfish, walleye, barracuda, scabbard and marlin, as well as seals and toothed whales, contain the highest average concentrations. While large tuna typically have levels of mercury that are similar to other large predatory fish, data indicate that the levels usually seen in canned tuna are substantially lower. This results from the fact that the tuna currently used for canned tuna are those of smaller size (US EPA 2001).

- The use of fishmeal as the feed for poultry and other animals used for human consumption may result in increased levels of mercury. In Germany, the poultry contains 0.03 - 0.04 mg/kg. Cattle are able to demethylate mercury in the rumen, and therefore, beef meat and milk contain very low concentrations of mercury (UNEP 2002).

- 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 (UNEP 2002).

- Predatory fish such as shark, swordfish, fresh and frozen tuna (not canned), have higher levels of mercury and should be consumed only occasionally. The health benefits of eating fish outweigh the risk of exposure to mercury if Health Canada consumption guidelines are followed. If you are an adult, limit your intake of these fish to no more than one meal per week. Pregnant women, women of child-bearing age and young children should be especially careful and limit their intake of these fish to no more than one meal a month (Health Canada 2004).

- The Australian Dietary Guidelines advise eating one or two fish meals (~150g fish per serve) per week for good health. The good news is that FSANZ has found it is safe for all population groups to eat 2-3 serves per week of most types of fish. There are only a few types of fish, which FSANZ recommends limiting in the diet – these are billfish (swordfish / broadbill and marlin), shark/flake, orange roughy and catfish. FSANZ advises that pregnant women, women planning pregnancy and young children continue to consume a variety of fish as part of a healthy diet but limit their consumption of certain species. Pregnant women, women planning pregnancy and young children should limit their intake of shark (flake), broadbill, marlin and swordfish to no more than one serve per fortnight with no other fish to be consumed during that fortnight. For orange roughy (also sold as sea perch) and catfish, the advice is to consume no more than one serve per week, with no other fish being consumed during that week (FSANZ 2004).

Symptoms

- The nervous system is very sensitive to all forms of mercury. Exposure to high levels of any types of mercury can permanently damage the brain, kidneys, and developing foetus. Effects on brain functions may result in irritability, shyness, tremors, changes in vision or hearing and memory problems. High exposures of mercury vapour may cause chest pain, shortness of breath, and a build up of fluids in the lungs (pulmonary oedema) that can be fatal. Methyl mercury and mercury metal vapours are especially harmful, because more mercury reaches the brain. Long term exposures may cloud the eye. Contact with mercuric chloride can cause burns to the skin and permanent damage to the eyes. Mercury also accumulates in the body (DEH 2004).

- Mercury affects the human brain, spinal cord, kidneys and liver. It affects the ability to feel, see, taste and move. It can cause tingling sensations in the fingers and toes, a numb sensation around the mouth and tunnel vision. Long-term exposure to mercury can result in symptoms that get progressively worse and lead to personality changes, stupor and coma. (HCWH 2002d).

- 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 (UNEP 2002).

- Inhalation of 1-3 mg/m3 for 2-5 hours may cause headaches, salivation, metallic taste in the mouth, chills, cough, fever, tremors, abdominal cramps, diarrhea, nausea, vomiting, tightness in the chest, difficulty breathing, fatigue, or lung irritation. Symptoms may be delayed in onset for a number of hours (Ingham County 2005).

- In fact, long before we had scientific facts to prove mercury's toxicity, there was evidence that mercury poisoning resulted in nerve damage. In the 1800's hat makers were exposed to mercury during the wool felting process. The strange and unpredictable behavior of Lewis Carroll's "Mad Hatter" in Alice of Wonderland was a portrayal of hat makers who had gone "mad" from mercury poisoning (HCWH 2002b). Hence the term "mad as a hatter" came from these symptoms from the use of mercury in the manufacturing of felt hats (Ingham County 2005).

- In pregnant women, mercury can pass through the placenta, where it affects fetal development by preventing the brain and nervous system from developing normally. Levels in the fetal brain are about 5 to 7 times that in maternal blood (Cernichiari et al. 1995). Affected children show lowered intelligence, impaired hearing and poor coordination. Their verbal and motor skills may be delayed. Because of these threats to the developing fetus, in countries like the U.S. the federal government recommends that women who are pregnant or who may become pregnant not eat mercury-contaminated fish (HCWH 2002d).

- The developing central nervous system is more sensitive to methylmercury than the adult. In infants exposed to high levels of methylmercury during pregnancy, the clinical picture may be indistinguishable from cerebral palsy caused by other factors, the main pattern being microcephaly, hyperreflexia, and gross motor and mental impairment, sometimes associated with blindness or deafness (Harada, 1995; Takeuchi and Eto, 1999). In milder cases, the effects may only become apparent later during the development as psychomotor and mental impairment and persistent pathological reflexes (WHO/IPCS 1990, NRC 2000, UNEP 2002).

- A child's developing nervous system is particularly sensitive to methyl mercury. Depending on the level of exposure, the effects can include a decrease in I.Q., delays in walking and talking, lack of coordination, blindness and seizures. In adults, extreme exposure can lead to health effects such as personality changes, tremors, changes in vision, deafness, loss of muscle coordination and sensation, memory loss, intellectual impairment, and even death (Health Canada 2004).

- Studies from one population exposed to methylmercury from fish also suggest an association with increased incidence of cardiovascular system diseases (Salonen *et al.*, 1995, Rissanen *et al.*, 2000). From research on animals there is evidence of genotoxicity and effects on the immune system and the reproductive system (UNEP 2002).

- Most of the scientific information on the harmful effects of mercury is based on the known effects of methylmercury, which is excreted very slowly from the body. Mercury poisoning can be acute, but usually results from repeated, chronic exposure to methylmercury. In humans, this is usually due to eating contaminated foods (mainly fish). Mercury poisoning affects the central nervous system, with symptoms such as lethargy, loss of appetite, weight loss, tremor, memory loss, sleep disturbance and confusion. It can also cause inflammation of the gums, loose teeth and a rash (Immunise Australia Program 2001).

- Methylmercury is highly toxic, and the nervous system is its principal target tissue. In adults, the earliest effects are non-specific symptoms such as paresthesia, a numbness or a "pins and needles" sensation, is the first symptom to appear at the lowest dose. With increasing exposure the person may experience malaise, and blurred vision increasing exposure, signs appear such as concentric constriction of the visual field, deafness, dysarthria (= Speech that is characteristically slurred, slow, and difficult to produce (and understand). The person with dysarthria may also have problems controlling the pitch, loudness, rhythm and voice qualities of their speech), ataxia (=Wobbliness. Incoordination and unsteadiness due to the brain’s failure to regulate the body’s posture and regulate the strength and direction of limb movements), and ultimately coma and death (Harada, 1995)(UNEP 2002).

- Mercury exposure in children can cause a severe form of poisoning termed acrodynia. Acrodynia is evidenced by pain in the extremities, pinkness and peeling of the hands, feet and nose, irritability, sweating, rapid heartbeat and loss of mobility (Ingham County 2005).

- Clinical Symptoms of Chronic Mercury Burden

- Behavioral Changes	- Depression	- Dermatitis
- Dizziness	- Fatigue	- Gum Disease
- Hair Loss	- Insomnia	- Allergic reactions or Asthma
- Muscle Weakness		

(Mineralysis 2002)

- Specific symptoms include tremors, emotional lability, insomnia, neuromuscular changes, and headaches. Chronic effects include central nervous system effects, kidney and thyroid damage, and birth defects (UNEP 2002). Genetic damage is also suspected (Ingham County 2005). High exposures have also resulted in death.

- Nervous system effects. These are the most critical effects of chronic mercury exposure from adult exposure as they are consistent and pronounced. Some elemental mercury is dissolved in the blood and may be transported across the blood/brain barrier, oxidized and retained in brain tissue. Elimination from the brain is slow, resulting in nerve tissue accumulation. Symptoms of chronic mercury exposure on the nervous system include: Increased excitability, mental instability, tendency to weep, fine tremors of the hands and feet, and personality changes (Ingham County 2005).

- Kidney effects: Kidney damage includes increased protein in the urine and may result in kidney failure at high dose exposure (Ingham County 2005).

- Birth defects: Neurological damage from methyl mercury. The manifestations of mild exposure include delayed developmental milestones, altered muscle tone and tendon reflexes, and depressed intelligence (Ingham County 2005).

TESTING

- The determination of blood or urinary mercury body burden is only useful in cases of acute intoxication. As heavy metals are quickly deposited in body tissues, metal level determinations are poor indicators of the body burden in cases of chronic low-level exposure. Tissue Mineral Analysis (TMA) can determine the extent of chronic exposure (Mineralysis 2002).

- Mercury has been measured in human hair forensic studies, for dietary reasons, in toxic and healthcare work and to examine environmental concentrations in polluted and unpolluted regions. The assumption that concentration of mercury in hair is proportional to the amount of mercury in blood, and should therefore reflect the body load of the metal, has been extensively studied and demonstrated. It is therefore not only possible to estimate the body burden of mercury, but also, knowing the rate of hair growth it is feasible to recapitulate the body burden in past months.

- Methyl mercury avidly accumulates in growing scalp hair. Once absorbed into the body, methylmercury accesses the hair follicle through the blood that bathes the hair root. Concentrations in hair are proportional to simultaneous concentrations in blood but are about 250 times higher. They are also proportional to concentrations in the target tissue, the brain (Cernichiari et. al. 1995). Longitudinal analysis of strands of scalp hair can recapitulate past blood and brain levels (Amin-Zaki et. al. 1974). Hair and blood are used as biologic indicator media for methyl mercury in both the adult and fetal brain (in the latter case, maternal hair or cord blood) (Clarkson 2002, Mineralysis 2002).

4.1 Case-Studies

- A tragic and now infamous event which occurred in Minamata Bay - Japan in the 1953, highlighted the dangers of inorganic mercury as a water pollutant when organic mercury by-products of industrial-scale acetaldehyde production were directly discharged in the local bay and methylated by microorganisms in anaerobic sludge lying at the bottom of the bay. In 1960, organic methylmercury was finally detected in seafood eaten by the local population. The poisoning affected 397 villagers resulting in 68 people deaths and 22 severe birth defects. Mercury poisoning is still sometimes referred to as Minamata disease (Mineralysis 2002, UNEP 2002).

- Mass poisonings have also occurred in various parts of the world where organomercury (short-chain alkyl mercury) compounds have been used as fungicides to treat seed grain (especially for cereal crops). The treated grain should not be used as food but if it is used to feed livestock, the meat becomes contaminated. One such large-scale poisoning incident occurred in rural Iraq in the winter of 1971-1972 when these mercuric fungicides were used to treat cereal grain. This involved 6000 people and resulted 500 deaths. An epidemiologic follow-up suggested that as many as 40,000 individuals may have been poisoned. (Mineralysis 2002, UNEP 2002, Clarkson 2002).

- 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). Data indicate exposures are generally higher in countries where fish consumption is higher, such as Greenland and Japan (UNEP 2002).

- A recent study published by scientists from the National Institute for Minamata Disease casts even more doubt on claims that regular fish consumption poses a threat to pregnant women and their unborn children. In a study conducted between 1999 and 2002, mercury hair measurements for over 8,000 Japanese individuals suggested that approximately 74 percent of females of childbearing age (15-49 yrs), had hair mercury levels exceeding EPA's Reference Dose (Yasutake et al. 2004). This is especially interesting in light of international educational achievement scores in which Japanese children consistently score higher than children in the United States. For instance, Japanese children in the fourth grade scored significantly higher in mathematics. In the eighth grade scores, Japanese children outperformed U.S. children in mathematics and science achievement (International Association for the Evaluation of Educational Achievement, *Mathematics (Science) Achievement in the Primary School Years: Third International Mathematics and Science Study*, 1997, Table I.I.; International Association for the Evaluation of Educational Achievement, *TIMSS 1999 International Science Report: Findings from IEA's Repeat of the Third International Mathematics and Science Study at the Eighth Grade*, 2000, Exhibit I.I. In: Pombo & Gibbons 2005). Overall, Japanese children are educationally outperforming U.S. children. This fact directly undercuts claims that mercury exposure in utero will negatively affect children's IQ (Pombo & Gibbons 2005).

- In the industrial cities of Harbin, China, Feng *et al*. (1998) found the correlation between methylmercury and total mercury concentrations was low, indicating that exposure was mainly in the form of elemental or inorganic mercury.

- The consumer council recently conducted a study on the heavy metals concentration of 12 different brands of "water melon extract"- a traditional Chinese drug for mouth ulcers and gum inflammation. Two brand types were found to have levels of mercury exceeding the existing limit 13 times. With no clear prescription printed on the package, consumers often assess it's medical credibility by personal experience alone. A person's health can be seriously affected consuming excessive levels of mercury (Mineralysis 2002).

- In 1998, (Dickman et. al. 1999) studied the relationship between Hong Kong male fertility and mercury in seafood. Hair mercury concentrations in fertile males were shown to increase with age (ages 25-72). Men with higher levels were found to be twice as likely to be subfertile. Individuals that ate fish or shellfish more than four times per week had significantly higher mercury concentrations in their hair than those who ate fish and shellfish less frequently. Hong Kong vegetarians who had consumed no seafood for the previous five years had the lowest hair mercury levels (1.21 versus 3.33 mg/kg for Hong Kong non-vegetarians - equivalent to 0.12 versus 0.33 mg%) (Mineralysis 2002).

- Both blood and hair (i.e. Tissue) mercury levels of children in Hong Kong was elevated and correlated with the frequency of fish consumption (Ip et. al. 2004).

CHAPTER 5 MERCURY-CONTAINING PRODUCTS AND THEIR ALTERNATIVES/SUBSTITUTES

- Exposure to mercury used to be mainly an occupational hazard rather than an environmental one. Mercury has become an environmental pollutant through industrial use of mercury in the manufacture of plastics, paper and batteries with the resultant discharge of the contaminated effluents into lakes and rivers (Mineralysis 2002).

- 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 (UNEP 2002).

- However, many of the uses discontinued in some countries (i.e. OECD) 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 (UNEP 2002).

- According to Logan, gas technologies are up to 20% more efficient than those run by coal. Also, for every 30 billion cubic feet of natural gas used in place of coal, carbon dioxide emissions decline by approximately 20 million tons (Schmidt 2002).

5.1 Mining (e.g. artisanal gold-mining) and Industrial (e.g. chlor-alkali, cement kilns) Applications

- Elemental mercury may be found in higher concentrations in environments such as gold mine sites where it has been used to extract gold (USGS 2000). Large quantities of liquid mercury are used to extract the sedimentary gold found in riverbeds. Pure gold is recovered when the mercury is evaporated from the amalgam by heating (Clarkson 2002).

- Mercury releases from chlor-alkali operations can be entirely eliminated only by converting to a non-mercury process such as the membrane cell process. The fact that the membrane cell process is more energy efficient (Fauh 1991) is one of several strategic and economic considerations that must be taken into account when a company decides to dismantle a mercury cell chlor-alkali facility and replace it with membrane technology (UNEP 2002).

- The cement industry requires energy to produce cement, and coal will remain an important input for the global cement industry. A number of coal producers and cement plant operators have identified and developed strong long-term relationships for the supply of coal to meet all or part of the energy needs of the plant (ACA 2005).

- Coal combustion products (CCPs), such as fly ash also play an important role in cement manufacture and in the construction industry generally. When Fly Ash is added to concrete, the spherical particles act like ball bearings in the mix, improving the workability and fluidity of concrete as well as the grading curve of the concrete mixture (ACA 2005). However, fly ash that contains mercury as a contaminant should not be used, as it slowly leaches into the surrounding environment.

5.2 Electrical

- Have you ever wondered why some light switches don't have a "click" when you turn them on or how your curling iron "knows" when to shut off? Many common household products and appliances contain mercury switches. Products that you might not suspect, such as your steam iron, contain mercury tilt switches.

- Mercury switches are widely used because of the conductive and liquid-like properties of the metal. Tilt and float switches operate exactly as you might expect. In a tilt switch as the switch is "tilted" the mercury rolls with the switch to complete the circuit. Float switches are usually used in situations where water levels are of concern like sump pumps and bilge pumps in boats. As the water levels rise the mercury inside the switch moves to complete a circuit which then turns the pump on or off.

- A small electrical switch could contain 3.5 grams of mercury and industrial switches can have as much as eight pounds of mercury (National Wildlife Federation 2000).

- The options for purchasing products without mercury switches are limited, in part because of lack of awareness of the use of mercury in some applications, as well as the benefits of alternatives. However for most applications, there are alternatives to mercury switches that manufacturers can use. For example, electric, mechanical and copper ball switches are available (Kuiken 2002).

5.3 Batteries

Batteries (medical use)

■ Alarms	■ Blood analyzers	■ Defibrillators	■ Hearing aids
■ Meters	■ Monitors	■ Pacemakers	■ Pumps
■ Scales	■ Telemetry transmitters	■ Ultrasound	■ Ventilators

Batteries (non-medical uses) Lamps

■ Fluorescent	■ Germicidal	■ Ultraviolet

■ High-intensity discharge (high pressure sodium, mercury vapor, metal halide) (HCWH 2002c)

5.4 Medicinal

Examples:

"Water melon extract"- a traditional Chinese drug for mouth ulcers and gum inflammation. Other Chinese herbal medicines with measurable amounts of mercury include: Chinese herbal ball preparations containing both mercury and arsenic include:

- An Gong Niu Huang Wan
- Da Huo Luo Wan
- Dendrobium Moniliforme (Night Sight pills)
- Ta Huo Lo Tan
- Niu Huang Chiang Ya Wan
- Niu Huang Chiang Hsin Wan
- Tsai Tsao Wan

(CPCS 2002)

5.5 Dental

- Dental amalgam fillings contain elemental mercury in concentrations up to 50% (Mineralysis 2002).
- Elemental mercury from dental fillings doesn't generally pose a health risk. There are, however, a fairly small number of people who are hypersensitive to mercury. While Health Canada does not recommend that you replace existing mercury dental fillings, it does suggest that when the fillings need to be repaired, you may want to consider using a product that does not contain mercury (Health Canada 2004).

- Pregnant women, people allergic to mercury and those with impaired kidney function should avoid mercury fillings. Do not have mercury fillings removed when you are pregnant because the removal may expose you to mercury vapour. When appropriate, the primary teeth of children should be filled with non-mercury materials (Health Canada 2004).

5.7 Lamps

- Use of fluorescent lamps is an excellent way to conserve energy and reduce the amount of mercury that is emitted from power plants. The problem is that each bulb contains mercury that eventually makes its way into the environment when improperly disposed of in a landfill or burned in an incinerator (Inform 2003).

- A typical light bulb consists of a phosphor coated glass tube with electrodes at either end. The tube is filled with mercury vapor that is excited to a higher electronic state when electricity is passed through the lamp. As the mercury is energized it emits ultraviolet radiation (UV), which is absorbed by the phosphor-coated glass causing it to fluoresce and emit visible light. Without the mercury vapor producing the UV energy there would be no light (Inform 2003).

- Some fluorescent lamps have as little as 3.5 mg mercury, but some have as much as 60 mg. Over the past 20 years, the mercury content of these lamps has declined steadily (Inform 2003).

- Currently no mercury-free alternatives currently exist for fluorescent lamps, which are well known for their low energy consumption. (Kuiken 2002).

- Work has been done, however, to reduce the amount of mercury needed in each lamp. From typical amounts of 20-40 mg of mercury per lamp, lamps with only 3 mg of mercury are commercially available today. Unfortunately these modern low mercury lamps have difficulty in competing on price with the higher-mercury lamps, and consumers are generally unaware of the difference between them (UNEP 2002).

Lamps that Contain Hg (Kuiken 2002)

Product	**Source of Mercury**	**Alternative**
Fluorescent: general purpose straight, U-bent, compact, high output black lights, "bug zapper" devices	Bulbs contain Hg	Low Hg bulbs are available**
High intensity discharge: Hg vapour, high pressure sodium, metal halide (street lamps and flood lights)	Bulbs contain Hg	High-pressure sodium Hg-free lamps have recently been developed
Germicidal lamps: hot cathode, cold cathode, slimline	Bulbs contain Hg	No alternative available
Neon lamps	Bulbs contain Hg	Some red colours do not contain Hg. For other colours, no alternative available.

** Certain low mercury lamps do not necessarily contain significantly lower amounts of mercury. A chemical is added in the process that binds the mercury and allows the lamps to pass the TCLP leaching test. Philips Alto T8 lamps contain 3.5 mg of mercury which is significantly lower than GE and Osram Sylvania's "low"mercury T8 lamps, which contain 6-9 mg of mercury. [1]

[1] John Reindle, Status of Local, State and Federal Mercury Project Legislation and Laws. 2001–2002 Legislative Sessions, June 28, 2002

5.8 Computers

- Mercury is used throughout the entire computer: in the circuit boards, electrical switches, and batteries (UNEP 2002).

- No mercury-free alternative currently exists (Kuiken 2002).

- There are a few alternatives currently available. IBM has developed a flat screen monitor that utilizes a software-controlled pivoting device to replace mercury switches used on the backs of monitors that initiate the tilt and complete the circuit. In addition, flat panel displays for desktop computers along with flat screen Liquid Crystal Display (LCD) screens used in laptop computers rely on fluorescent lamps to provide the backlighting. OSRAM-Sylvania has developed a mercury-free backlight for LCD screens, which uses xenon gas instead of mercury to create the light (UNEP 2002).

5.9 Thermometers

- ■ Body temperature thermometers
- ■ Clerget sugar test thermometers

■ Heating and cooling system thermometers
■ Incubator/water bath thermometers
■ Minimum/maximum thermometers
■ National Institute of Standards and Technology calibration thermometers
■ Tapered bulb (armored) thermometers (HCWH 2002d)

- Mercury thermometers are made of glass and are about the size of a straw, with a silvery-white liquid inside. Mercury fever thermometers have been used for decades as a first step in caring for someone who feels sick. But, ironically, the mercury thermometer can be a risk to the health of families and communities (HCWH 2002e).

- Mercury is a toxic substance that can harm both humans and wildlife. Many families have had a mercury thermometer in their medicine cabinet for years without breaking it. But mercury thermometers are very easy to break and very difficult to clean up. To function properly, mercury thermometers must be “shaken down” before use, creating a constant high potential for breakage. Public health officials across the country report a steady stream (over 18,000 to poison control centers in 1998 alone) of concerned calls from broken mercury thermometers (HCWH 2002e).

- Sometimes mercury from the broken thermometer spills into a crack in the floor or soaks into a carpet. If mercury spills from a thermometer and is not cleaned up, it will all evaporate, potentially reaching dangerous levels in indoor air. A single broken fever thermometer, containing 0.5 to 1.5 grams of mercury, is enough to create a health risk if it evaporates into a small, poorly ventilated room (HCWH 2002d). For example, if a mercury thermometer breaks in a room of 45m3 in size, the level of mercury can exceed 20 times the safe level

- Several types of non-mercury thermometers are available commercially. These include:

■ Digital electronic thermometers
■ Glass gallium-indium-tin (galinstan) thermometer
■ Flexible forehead and ear canal thermometers (UNEP 2002)

- A recent statement by the American Medical Association indicated that non-mercury fever thermometers **are** adequate diagnostic tools (HCWH 2002c)

- The known environmental damages caused by alternative thermometers are significantly less than those presented by mercury thermometers. The primary environmental concern arising from use of alternative thermometers relates to the disposal of button cell batteries used in digital electronic or ear canal thermometers. Button cell batteries used in digital thermometers contain significantly less mercury than a mercury thermometer—roughly 3.5 to 11 milligrams of mercury per battery. When a mercury thermometer or a button cell battery is thrown away and burned in an incinerator, much of the mercury that it contains is likely to be emitted to the atmosphere. However, a mercury thermometer that breaks in the home, or that breaks in the solid waste system prior to burial in a landfill, will release significantly more of its mercury than will a button cell battery (HCWH 2002c).

5.8 Thimerosal

The situation in China in regards to the preservative thimerosal in vaccines is unknown. The following information is for countries, such as Australia and the U.S.

- Thiomersal (or thimerosal) is an organic compound containing 49.6% mercury by weight. Thimerosal's chemical name, which describes it's composition is Sodium Ethylmercuric Thiosalicylate. It has been used in very small amounts in vaccines since the 1930s, a preservative to prevent bacterial and fungal contamination (Immunise Australia Program 2001). However, the U.S. EPA later lowered its allowable safe long-term daily intake for mercury. As a result, a more recent review of thimerosal by the FDA raised questions about possible health risks (Clarkson 2002).

- The current debate linking the use of thimerosal in vaccines to autism and other developmental disorders has led many families to question whether the potential risks associated with early childhood immunizations may outweigh the benefits (Fox, M. 2005).

- It took just over eight days to completely clear mercury from thimerosal, while it took 21 days to clear methyl mercury from the blood, they found. (Fox, M. 2005)

- "This study emphasizes that thimerosal and methyl mercury behave differently in the body." said Dr. Jim Burkhart, science editor for the journal. (Fox, M. 2005)

- It is metabolized or degraded to ethylmercury and thiosalicylate (FDA 2005).

- In the U.S., Thimerosal has been removed from or reduced to trace amounts in all vaccines routinely recommended for children 6 years of age and younger, with the exception of inactivated influenza vaccine A preservative-free version of the inactivated influenza vaccine (contains trace amounts of thimerosal) is available in limited supply at this time for use in infants, children and pregnant women. Thimerosal is primarily used in multiple-dose vaccines (e.g. Hepatitis B, Japanese Encephalitis, Influenza). Some vaccines such as Td, which is indicated for older children ($\geq$ 7 years of age) and adults, are also now available in formulations that are free of thimerosal or contain only trace amounts. Vaccines with trace amounts of thimerosal contain 1 microgram or less of mercury per dose (FDA 2005). '

- Allergic responses to thimerosal are described in the clinical literature, with these responses manifesting themselves primarily in the form of delayed-type local hypersensitivity reactions, including redness and swelling at the injection site (Cox and Forsyth 1988; Grabenstein 1996). Such reactions are usually mild and last only a few days. Some authors postulate that the thiosalicylate component is the major determinant of allergic reactions (Goncalo et al. 1996). In a clinical setting, however, it is usually not possible to determine whether local reactions are caused by thimerosal or other vaccine components (FDA 2005).

- The various mercury guidelines are based on epidemiological and laboratory studies of methyl mercury, whereas thimerosal is a derivative of ethyl mercury. Because they are different chemical entities - ethyl- versus methylmercury - different toxicological profiles are expected. There is, therefore, an uncertainty that arises in applying the methylmercury-based guidelines to thimerosal. Lacking definitive data on the comparative toxicities of ethyl- versus methylmercury, FDA considered ethyl- and methyl-mercury as equivalent in its risk evaluation (FDA 2005 or Resources Committee ?).

- Magos et al. directly compared the toxicity of ethyl- versus methylmercury in adult male and female rats administered 5 daily doses of equimolar concentrations of ethyl- or methylmercury by gavage (Magos et al 1985). Magos concluded that ethylmercury, the mercury derivative found in thimerosal, is less neurotoxic than methylmercury, the mercury derivative for which the various guidelines are based (FDA 2005).

- One final piece of data regarding thimerosal is worth noting. At the initial National Vaccine Advisory Committee-sponsored meeting on thimerosal in 1999, concerns were expressed that infants may lack the ability to eliminate mercury. More recent NIAID-supported studies at the University of Rochester and National Naval Medical Center in Bethesda, MD examined levels of mercury in blood and other samples from infants who had received routine immunizations with thimerosal-containing vaccines. [Pichichero ME, et al. Lancet 360:1737-1741 (2002)] Blood levels of mercury did not exceed safety guidelines for methyl mercury for all infants in these studies. Further, mercury was cleared from the blood in infants exposed to thimerosal faster than would be predicted for methyl mercury; infants excreted significant amounts of mercury in stool after thimerosal exposure, thus removing mercury from their bodies. These results suggest that there are differences in the way that thimerosal and methyl mercury are distributed, metabolized, and excreted. Thimerosal appears to be removed from the blood and body more rapidly than methyl mercury. NIAID is sponsoring a follow-up study with larger numbers of infants in Buenos Aires where thimerosal-containing vaccines are still administered to children. See the NIH/NIAID vaccines/thimerosal web site http://www.niaid.nih.gov/factsheets/thimerosalqa.htm (FDA 2005).

More examples of uses of mercury and their alternative/substitute

Sector	Product	Source of Mercury	Alternative Product
Appliances (major)	Gas ranges and refrigerators	Hg flame sensor	Electric ignition rings
	Attic fans	Tilt switch (air flow/fan limit controls)	Alternative switches are available
	Bilge pumps	Hg float switch for auto shut-off	Alternative switches are available, mfrs are phasing out
	Central air-conditioners	Tilt switch	Alternative switches available
	Chest freezers	Tilt switches (in lid light)	Mercury is being phase out of new models
Appliances (minor)	Steam iron with 15 minute shutoff	Tilt switch	Alternative switches available
	Curling irons	Tilt switch (for auto shut-off)	Look for one hour timer features
	Door bell	Tilt switch for “ding-dong”	-
	Electric space heaters	Tilt switch (safety shut-off)	Newer models many not contain Hg
	Electric organs	Switches for non-keyboard controls	
	Fluid level controls	Tilt switches mounted on float, lever arm, or on plunger of sump pump	Most new floats are made without mercury-look for magnetic dry reed switches, optic sensors, or mechanical switches
	Commercial popcorn	Tilt switch	Alternative switches available

	poppers Portable phones "Ride control" automatic leveling suspension Security alarms "Silent" wall switch Sump pump Vanity mirror	 Tilt switch Tilt switch Tilt switch Tilt switch Mercury float switch Tilt switch	 Alternative switches available Mechanical switch Mechanical switch Mechanical light switch - Mechanical switch
Automobiles	Headlights Glove box Hood and trunk lights	Mercury-containing bulbs Tilt switch Tilt switch	Incandescent bulbs Ball-type switch or mechanical switch Ball-type switch
Building Materials	Thermostats	Tilt switches	Electronic thermostats
Computers	Laptop computer screens	Fluorescent lamps used for backlighting	*Alternatives are not readily available although alternative technology exists*
Electrical Equipment	Button cell batteries Thermostats	Component of battery Tilt switches (1-6 switches per unit)	*No alternative currently available* Electronic thermostat
Healthcare	Sphygmomanometer	Blood pressure device that contains Hg	Aneroid or electronic versions
Laboratory Uses	Reagents	Mercury is a component of many chemicals	Alternative procedures or reagents are available for many tests
Lamps	Fluorescent	Bulbs contain Hg	*Some Hg-free alternatives are in development (e.g. carbon lamp in Sweden)*
Personal Care Products	Cosmetics	Mercury is used as a preservative	Hg-free alternatives are available
Pharmaceuticals	• Contact lens solutions and other ophthalmic products containing thimerosal or phenylmercuric nitrate • Diuretics with mersalyl and mercury salts • Early pregnancy test kits with mercury-containing preservative • Merbromin/water solution • Nasal spray with thimerosal, phenylmercuric acetate or phenylmercuric nitrate • Vaccines with thimerosal (primarily in hemophilus, hepatitis, rabies, tetanus, influenza, diphtheria and pertussis vaccines) • Cleaners and degreasers with mercury-contaminated caustic soda or chlorine		

Miscellaneous	Jewellery Light-up shoes	Mercury in vial or as switch for light up jewellery Mercury switch	Avoid purchasing Discontinued, avoid buying second hand
Industrial processes	PVC production	Mercury is used as a catalyst in the Chlor-Alkali process	Membrane-cell process
Mining processes	Gold extraction	Mercury is amalgamated with gold particles for recovery.	Non-mercury processes are available

(Kuiken 2002, UNEP 2002, HCWH 2002c)

- In most cases the price for mercury-free products is comparable to their mercury counterpart (Kuiken 2002).

- Mercury has been entering product lines where consumers would least expect it, such as automobile headlamps—the new blue tinted headlights are high intensity discharge lamps that contain mercury. Without a federally mandated labeling law or a complete ban on mercury, new products will likely be designed without the knowledge of consumers or procurement officers (Kuiken 2002).

- Users of mercury-containing products are faced with four main obstacles to the use of viable alternatives. These include:

• The need for developing and testing efforts, e.g. required for security reasons;
• Higher costs and competition;
• Attitudes to, and knowledge of, alternative techniques – even among equipment suppliers;
• Internationally standardised measurements.

CHAPTER 6 POLICY AND MANAGEMENT

Background

- 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 (UNEP 2002).

- The specific methods for controlling mercury releases from these sources vary widely, depending upon local circumstances, but fall generally under:
  - A. "Preventive Measures" which prevent some uses or releases of mercury from occurring at all.
    - i. Reducing mercury mining and consumption of raw materials and products that generate mercury releases;
    - ii. Substitution (or elimination) of products, processes and practices containing or using mercury with non-mercury alternatives;
  - B. "Control Measures" which reduce (or delay) some releases from reaching the environment
    - i. Controlling mercury releases through end-of-pipe techniques;

ii. Mercury waste management (UNEP 2002)

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 (UNEP 2002).

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

- This 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 (UENP 2002).

- 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. 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 (UNEP 2002).

- 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 (UNEP 2002).

ii. Substitution of products and processes containing or using mercury

- 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 (UNEP 2002).

- 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 practices (UNEP 2002).

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

- Pre-treatment measures;
- Combustion modifications; and
- Flue gas cleaning or end-of-pipe controls.

- 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 (UNEP 2002).

- Processing of mineral resources at high temperatures, such as combustion of fossil fuels, roasting and smelting of ores, kiln operations in the cement industry, as well as incineration of wastes and production of certain chemicals, results in the release of a number of volatile trace elements into the atmosphere (UNEP 2002).

- It is often believed that a combustion unit – typically used for power generation or waste incineration – with an emission control device removes most or all of the mercury and other heavy metals emitted during combustion. However, unlike other heavy metals, mercury has special properties that make it difficult to capture in many control devices. While some units with control devices do remove mercury quite effectively (UNEP 2002).

- Concentrations of mercury in coals and fuel oils vary substantially depending on the type of fuel and its origin. The mercury in coal may be associated with the organic or the inorganic constituents (mineral matter) of coal. When it is associated with mineral matter such as sulfides it can often be removed by physical coal cleaning techniques. The removal of mercury from the organic fraction of coal is much more difficult and costly (UNEP 2002).

- Fly ash and other surfaces within the combustion system can catalyze or mediate mercury oxidization reactions. Major factors that affect mercury speciation are the fuel (or waste) composition, the combustion conditions, and the type of flue gas cleaning methods used (UNEP 2002).

- 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 (UNEP 2002).

- Some countries rely on controlled waste incineration, which reduce the waste volume and make use of the energy bound in the waste materials. Because of its low boiling point, most of the mercury is thermally released during the combustion, and will be emitted directly to the atmosphere, unless the exhaust gas is filtered effectively. In some industrialised countries filter facilities on waste incinerators have been improved during the last decade or two, and this is also reflected in decreased emissions of mercury (AMAP, 2000). Generally, only about 35-85 percent of the mercury is retained by filtering (Pirrone *et al.*, 2001), and parts of the mercury will still be emitted directly to the environment. However, carbon injection followed by filtration can increase the retention rate significantly. Mercury retention close to 100 percent is not normal. The mercury eliminated from the exhaust gas is retained in incineration residues and, for some types of filtering technology, in solid residues from wastewater treatment (from scrubbing process). These residues are stored in landfills with the implications described above, or – depending of their content of pollutants – used for special construction purposes (under roads or similar). In some cases such solid residues are stored in special deposits for hazardous waste, which are additionally secured with top membranes eliminating or reducing evaporation and leachate production from the waste (UNEP 2002).

C. Flue gas treatment (end-of-pipe) controls

- Wet Flue Gas Desulphurisation (FGD) Systems
- Dry FGD Systems
- Mercury-Bearing Particle Emissions
- Coal-fired power plants and municipal incinerators are most frequently equipped with either electrostatic precipitators (ESPs) or fabric filters. (UNEP 2002)

ESPs are particularly efficient in removing all types of particles with diameters larger than 0.01 μm, including those bearing mercury after condensation within exhaust gases. Particles containing trace elements are concentrated mostly in two size ranges: 1) at ca. 0.15 μm diameter and 2) between 2 and 8 μm diameter. Mercury can be found on particles in both size ranges. ESPs can tolerate operating temperatures as high as 720 K (Pacyna and Pacyna, 2000).

- **Fabric filters** are also used in coal-fired power plants. The particle collection efficiency (not the same as the mercury collection efficiency) is always very high, and even for particles of 0.01 μm diameter, exceeds 99 percent. However, the durability of fabric filters is very dependent upon the working temperature and their resistance to chemical attack by corrosive elements in exhaust gases. The temperature of exhaust gases often exceeds the temperature tolerance for fabric filter material, and therefore limits the application of fabric filters (Pacyna and Pacyna, 2000). According to comments from the US, fabric filters capable of temperatures seen in coal-fired boilers are available in the US (UNEP 2002).

- Some control technologies typically serve to reduce emissions of more than one pollutant and, in fact, have been driven for the most part by acid rain emission controls. For example, wet scrubbers reduce both SO_2 and mercury. The technology for NO_x reduction (selective catalytic reduction, or SCR) has also been found to oxidize elemental mercury that can be effectively captured in a downstream wet scrubber. The conversion (fuel switching) of coal-fired boilers to burn natural gas (in a simple cycle gas-fired boiler or combined cycle gas turbine) offers great potential to reduce emissions of SO_2 and mercury (almost 100 percent) and NO_x (70 to 80 percent). Baghouses (FFs) and electrostatic precipitators (ESPs) control fine particles and some mercury, while the combination of the two substantially reduces mercury emissions. These are examples where multi-pollution controls may reduce mercury emissions, while specific mercury controls may not be economically feasible (NEG/ECP, 2000).

- **Flue gas treatment, or end-of-pipe, controls** are currently deployed for control of SO_2, NO_x, and PM: SO_2 controls include a variety of wet and dry scrubbers; NO_x may be controlled by selective catalytic or selective non-catalytic reduction; and PM may be controlled by fabric filters (FFs) or electrostatic precipitators (ESPs). There has been extensive testing of the mercury removable capabilities of these systems on a wide range of coal-fired utility boilers in the USA. The average results ranged from 0 to 96 percent dependent on a variety of factors as described in detail below. Generally speaking:

 A specific technology, or combination of technologies, produced a range of mercury reduction for any coal type (UNEP 2002);

 The type of coal strongly affected the mercury control achieved, with average percent removal increasing as coal "rank" increased from lignite through subbituminous to bituminous. Within any given rank, a range of removals was achieved. Note also that world coals represent a wider range of coal rank (e.g. brown coal) and characteristics (e.g. sulfur, ash) than US coals (UNEP 2002).

- Research so far has indicated that the most cost-effective approach to mercury control may be an integrated multipollutant (SO_2, NO_x, PM, and mercury) control technology. A number of these technologies are in the pilot-scale development stage in the USA, but have generally not yet been demonstrated at full-scale. Recent Swedish experience has demonstrated the economic as well as technical efficiency of such systems in full-scale waste incinerators and utility burners (Hylander *et al.*, 2002, as cited in comments from Uppsala University, Sweden) (UNEP 2002).

- Distribution of mercury within the various streams of wet flue gas desulfurisation (FGD) systems has been studied in a number of countries. These studies have shown that mercury capture in wet FGD systems depends on the rank of coal burned, and the design and operating conditions of the FGD system. Wet FGD scrubbers were generally preceded by PM control devices (i.e., ESPs or FFs). The total amount of mercury captured in a boiler equipped with a scrubber depended on the amount of mercury captured in the upstream PM control device and the soluble Hg^{2+} captured by the scrubber. Flue gas from the exhausts of units burning bituminous coals exhibited higher levels of Hg^{2+} than flue gas from burning of lower rank coals; this mercury was readily captured in the PM control device and downstream scrubber. Mercury in the exhausts of units burning low rank coals tended to be Hg^0, and mercury capture in these units tended to be minimal. The scrubber chemistry must also be controlled to insure that Hg^{2+} that is dissolved in the scrubber liquor is not converted back to Hg^0 and re-entrained in the flue gas. Scrubber sludges must also be handled in an environmentally acceptable manner (UNEP 2002).

- Major factors that affect mercury speciation are the fuel (or waste) composition, the combustion conditions, and the type of flue gas cleaning methods used. Coal rank and chlorine content are extremely important factors in the speciation and capture of mercury with different types of air pollution control technologies. In the USA, bituminous coals tend to have relatively high concentrations of chlorine (Cl). This can result in the oxidization of Hg^0 to Hg^{2+} (primarily $HgCl_2$). The Hg^{2+} can be adsorbed onto fly ash carbon and captured in an ESP or FF. Bituminous pulverized-coal (PC) fired boilers equipped with an ESP or FF may exhibit total mercury captures ranging from 20 percent to more than 90 percent. The higher levels of capture are believed to be associated with a higher fly ash carbon content. However, carbon in fly ash can negatively impact its use as a by-product in concrete, as well as negatively impact plant heat rate. Units that burn bituminous coal, and that are equipped with dry flue gas desulfurization (FGD) scrubbers or wet FGD scrubbers, also exhibit high levels of mercury capture. In contrast, low rank US coals (subbituminous coal and lignite) are alkaline, have a relatively low chlorine content, and have fly ash with a low carbon content. Mercury in the exhausts of plants burning low rank coals tends to be predominately Hg^0. The capture of mercury from the flue gas from these plants tends to be low, whether the units are equipped with an ESP, FF, dry FGD scrubber, or wet FGD scrubber (UNEP 2002).

- Various countries rely to a greater or lesser extent on controlled waste **incineration**, which reduces the waste volume and (optimally) makes use of the energy contained in the waste materials. Because of its low boiling point, most of the mercury content of the waste evaporates during combustion, and is emitted directly to the atmosphere, unless the exhaust gas is properly controlled. In many countries emission controls on waste incinerators have been improved during the last decade, and this is reflected in decreased emissions of mercury (AMAP, 2000). In units fitted with control technologies, Pirrone *et al.* (2001) found that 35-85 percent of the mercury is removed by flue gas controls (UNEP 2002).

- The mercury eliminated from exhaust gases is retained in incineration residues and, for some types of filtering technology, in solid residues from wastewater treatment (from the scrubbing process). These residues are generally sent to landfills or – depending upon their content of hazardous materials and other characteristics – used for special construction purposes (wallboard, roadbeds or similar). In some cases such solid residues are stored in special deposits for hazardous waste, which are additionally secured with a membrane or other cover that eliminates or reduces releases by evaporation and leaching (Pacyna and Pacyna, 2000).

8.3.4 Mercury removal from exhaust gases generated in industries other than utility boilers and incinerators

8.3.5 Reducing releases of mercury from chlor-alkali facilities

- Typical devices/techniques for removal of mercury from stack emissions are: 1) gas stream cooling to remove mercury from the hydrogen stream, 2) mist eliminators, 3) scrubbers, and 4) adsorption on activated charcoal and molecular sieves. The proper use of these devices can remove more than 90 percent of the mercury from the gas streams (Pacyna and Pacyna, 2000).

B. Technical measures

- Technical measures for dealing with mercury wastes may be divided between pre-treatment measures and emission control measures (UNEP 2002).

(1) Pre-treatment measures

• Prohibit or limit mercury releases to the environment by treating household waste, hazardous waste and medical waste by emission control technology (UNEP 2002).

(2) Emission control measures

• Require landfills to be properly licensed and equipped for the type of hazardous waste they accept, including membranes to prevent mercury from evaporating or leaching, collection and treatment of landfill effluent, routine and long-term testing of groundwater quality, air emissions, etc.;

• Ensure that mercury wastes are incinerated only at facilities equipped for hazardous waste, with best-available-technology dust collectors and flue gas control, etc.;

• Develop a facility (perhaps jointly with a neighboring country) for final disposal of mercury (and other) treated wastes that are so concentrated or hazardous over the long term that they cannot be responsibly disposed of in another manner.

- One of the only real long-term measures is prevention (keeping mercury out of the waste stream). Once present in the waste stream (if pollution control is considered a priority), mercury contributes to the need for emission controls on incinerators, special disposal of incinerator residues, landfill leachate treatment etc. – all associated with extra costs. Even those countries that make an effort to separate mercury products from the general waste stream have found it difficult to achieve satisfactory collection rates, and they have discovered that separate collection and treatment implies significant extra costs for society. Therefore, with regard to mercury in products, minimising the intentional use of mercury may be a highly desirable objective. This has been the main driving force behind the mercury substitution policy of many countries.

- Another long-term measure for mercury waste management is intermediate storage/definitive storage in a special facility

iv. Mercury waste management

- 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 (UNEP 2002).

- 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 (UNEP 2002).

8.4.3 Responsible management of mercury inventories

A. Take-up by Almadén

- One of the solutions proposed for mercury from decommissioned chlor-alkali facilities is shipping it to the Almadén mercury mine in Spain, which has agreed to decrease its mining production and to market the chlor-alkali mercury instead. Some feel that there are not yet adequate controls on where this mercury would then be sold by Almadén, or how it would be used.

B. Intermediate storage

- Another proposal is that the mercury could be stored safely for an indefinite period of time until a strategy for closed-loop re-use or safe disposal is available. This option has the advantage that the mercury would be available if some important new need is identified. It could lead to some releases, ongoing management costs, and is still not a final solution. However, ongoing management costs and the risk of significant releases outside the intermediate storage enclosure would be small if best management practices were implemented.

C. Terminal/permanent storage

- It has been argued that, from an environmental point of view, terminal/permanent disposal of mercury would be preferable. However, this could encourage continued mining and smelting of virgin mercury to meet ongoing demand. Further, it has been argued, the deposited mercury could be difficult if not impossible to recover if important new (and “closed-loop”) uses were to emerge in the future.

- Sweden has developed a strategy for terminal storage of surplus mercury and mercury containing waste. The strategy was developed as a response to concerns about what to do with the mercury collected from consumer products, industry and high-level mercury waste, which is currently in intermediate/provisional storage. Although the legal framework needs to be developed, and there are various technical issues related to waste treatment that need to be worked out, as well as the location and design of the terminal storage facility, a viable concept has been developed and proposed. The concept includes a suggestion that the waste owners bear full responsibility for constructing, managing and operating the facility. Excluding pre-treatment, estimates of the eventual cost of this option are on the order of $US 14-20 per kg of mercury. To put this figure in some perspective, this terminal storage cost would add 6-10 percent to the estimated cost of converting a chlor-alkali facility from the mercury process to the membrane process.

- Physical requirements for the terminal storage facility include geological stability, low water permeability, and absence of mineral resources which are or may become economically feasible to excavate. The terminal storage may be located in an abandoned mine shaft with well known geological and geohydrological characteristics.

- It is important to note that the concept of deep-rock terminal storage was not developed as a method to reduce current mercury releases to the environment or current exposures. Rather, it was designed as a long-term solution to the problem of storing mercury wastes - in light of the persistence of mercury and the need for long-term strategies to reduce mercury pollution.

- For example, for plants that sell their fly ash for cement manufacturing, the use of activated carbon injection could dramatically reduce their ability to sell this material due to increased carbon concentrations. For plants that elect to use a wet scrubber to capture mercury, their ability to sell their gypsum for use in wallboard manufacturing could be compromised by increased concentrations of mercury. The potential impacts of additional mercury control on the use of by-products or the disposal of residues have not yet been determined.

- 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.

- 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).

- **Waste incineration -** Legislation prescribing maximum allowable releases of a number of pollutants, including mercury, from incineration facilities for household and hazardous wastes respectively, to the atmosphere and wastewater, as well as specifications on the deposit of solid incineration residues exist in a number of countries. Indirectly, such legislation might dictate the use of a limited number of emission control technologies, which are capable of complying with the emission requirements. For example, some countries have extensive exhaust gas filtering on all waste incineration facilities (hazardous, medical and household waste), holding back a major part of the otherwise emitted mercury.

- **Use of solid incineration residues -** Legislation is also found prescribing maximum allowable concentrations of mercury, often together with other pollutants, in ashes and slag from waste incineration and fossil fuel combustion that can be used for construction purposes (roads, etc.), as well as in wastewater sludge to be used as fertiliser on agricultural land.

- **Waste treatment –** In a number of countries, especially those within the OECD, legislation exists prescribing separate collection and waste treatment of products and process waste containing mercury – for example batteries, fluorescent light tubes and dental amalgam filter residues. The aim of such legislation is to prevent or minimise the diffuse spreading of mercury-containing products and prevent dumping of process waste in the environment, as well as limiting the amounts of mercury containing waste in the general household waste stream (where it causes significant mercury emissions and increases waste treatment costs).

Measures/Tools

- The best-known **non-control-technology options** include such measures as:

• **Take Back Programs**: In instances where the use of mercury in products has not been eliminated, some states and in some instances, counties, have developed legislation requiring manufacturers to take their products back at the end of their life-cycle.

- Consumers can place pressure on manufacturers by insisting on take back programs, mandatory product labeling, and the proper recycling of products that contain mercury. For example, in Japan the Appliance Recycling Law requires manufactures to take back their mercury-containing products at the end of their life cycle at no cost to the consumer. The European Parliament recently adopted two initiatives requiring manufactures to assume full financial and/or physical responsibility for their products at the end of their consumer life cycle. They also adopted Restrictions on Hazardous Substances (ROHS), which will phase out the use of hazardous substances in the electronics industry including lead, mercury, hexavalent chromium and several types of brominated flame retardants (UNEP 2002).

• **Standards/Certification**
To ensure that products meet the minimum health and safety requirements; and provide assurance to consumers.

• **Labeling:** To better inform the buying public, legislation has been developed which requires manufacturers to label products that contain mercury.

• **Disposal Bans:** Restrictions on which products can be discarded into landfills and incinerated is another method that states have used to reduce the amount of mercury emitted into the environment

• **Product Sales and Use Bans:** The most effective way to keep mercury out of the environment is to eliminate its use entirely. Certain states have taken the lead in this area by restricting the amount of mercury-containing products sold within their borders (UNEP 2002)

Examples of Management Measures:

 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 (UNEP 2002);

 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 (UNEP 2002);

 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 (UNEP 2002).

 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 (UNEP 2002);

 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 (UNEP 2002);

 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 (UNEP 2002);

 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 nonmercury products (UNEP 2002);

 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 (UNEP 2002); Some states in the U.S. have adopted regulations or worked with dental associations on initiatives to address the use and/or disposal of mercury amalgam fillings (Kuiken 2002)

 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 (UNEP 2002);

 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 (UNEP 2002).

6.1 Education

- **Information and educational measures**

• Educate the public about proper disposal of mercury containing products;
• Provide collection points where the public may easily take these separated products;
• Devise several key indicators and publicize the progress that is being made with regard to responsible management of mercury (UNEP 2002).

- United Nations Industrial Development Organization (UNIDO) focuses on:

• On-the job training in cleaner technology;
• Training of women and women entrepreneurs, who have a big share in the sector;
• Enhancing awareness through workshops on local, regional and international level;
• Raising the interest of the media. Among others, BBC and CNN have already reported on the mercury-related activities of UNIDO. (UNEP 2002)

- The involvement and commitment of the local community is crucial, including the following elements:

• Clear community understanding of the problem;
• Commitment of community resources to deal with it;

• Meetings of all the stakeholders involved in the discussions to reach a consensus:
• After consensus is reached, a programme of action including: a) closed circuit utilization of mercury in the concentration/amalgamation steps; b) burning of the amalgam in retorts in the field, and use of fume hoods in gold dealers' shops; and c) confinement of processed material in specially built settling ponds;
• Agreement to adopt these measures both for the present operations and to avoid future problems;
• For the present operations, sampling the levels of mercury pollution, assessing risk areas, and carrying out isolating and remediating measures to ensure mercury fixation and/or recovery. (UNEP 2002)

- In order to successfully introduce alternatives to present polluting practices, one needs to:

• Familiarize local manufacturers with the design of low-tech but efficient gold recovery equipment;
• Demonstrate alternatives to amalgamation;
• Prove the cost effectiveness of the new techniques;
• Develop micro-financing programmes in cooperation with the private sector. (UNEP 2002)

- Other more obvious measures should also be implemented, such as:

• No spilling of mercury during the amalgamation phase, being a matter of mercury management throughout the process;
• Use of amalgamation vessels;
• Processing of the ore in a closed loop;
• Use of retorts in order to collect the mercury vapours;
• Use of fume hoods (preferably with carbon filters) at gold shops. (UNEP 2002)

6.3 Recycling

- A large "reservoir" of mercury is known to be contained in products still in use, and "on the users' shelves" in society. If properly collected, recycled and managed, this reservoir could be the source of all of society's needs for mercury for many years into the future. Attempts have been made to quantify these reservoirs of mercury in Sweden, the Netherlands and Denmark (UNEP 2002)

- 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. 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 (UNEP 2002).

6.5 Legislation and Voluntary Measures

- **Regulatory/prescriptive measures**

• Prohibit mercury in product waste and in process waste from being released directly to the environment, by means of an effective waste collection service;

• Prohibit mercury in product waste and in process waste from being mixed with less hazardous waste in the general waste stream, by ensuring separate collection and treatment;
• Set limit values for the allowable mercury content in sewage sludge spread on agricultural land;
• Restrict the use of solid incineration residues in road-building or other applications where its long-term control cannot be assured;
• Prohibit the re-marketing of used, recycled mercury;
• Prohibit illegal dumping of wastes;
• Prohibit any direct or indirect discharges of mercury to normal drains or the water treatment system, or any disposal of mercury in water;
• Prohibit or restrict cross-border transport of mercury (and other hazardous) wastes;
• Require that any mercury containing waste or materials stored on-site by an industry or commercial operation must be in air-tight and waterproof containers, and that the organization must have a written plan and schedule for eventual proper disposal of the materials;
• Prohibit the disposal on land of any sewage sludge, fertilizer, or other material that exceeds responsible international standards for mercury content;
• Put in place an environmental management strategy that includes responsible monitoring and enforcement of mercury regulations, tracking of all mercury movements (from raw material to process to product to waste), and periodic independent control.

(2) Economic measures

• Set taxes and fees on hazardous waste disposal (special incineration, dedicated landfill, etc.) that fully reflect the real long-term costs to society and the environment of responsibly dealing with these hazardous substances.

<u>Type and Aim of Measure:</u>

<u>Production and Use Phases of Life Cycle</u>

- Point Sources
  - Prevent or limit the intentional use of mercury in processes
  - Prevent or limit mercury from industrial processes (such as chlor-alkali and metallurgic industry) from being released directly to the environment
  - Apply emission control technologies to limit emissions of mercury from combustion of fossil fuels and processing of mineral materials
  - Prevent or limit the release of mercury from processes to the wastewater treatment system
  - Prevent or limit use of obsolete technology and/or require use of best available technology to reduce or prevent mercury releases

- Products
  - Prevent or limit products containing mercury from being marketed nationally
  - Prevent products containing mercury from being exported
  - Prevent or limit the use of already purchased mercury and mercury containing products
  - Limit the allowable content of mercury present as impurities in high volume materials
  - 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

- Mercury control options under consideration

- Prevent or limit the dedicated mining of virgin mercury from the Earth's crust
- Prevent or limit the marketing of mercury recovered as a by-product from other mineral or fossil fuel extraction (such as non-ferrous mining activities and natural gas cleaning)
- Control trade of pure mercury in order to restrict it to pre-defined essential uses and secure environmentally safe handling (similar to procedures for hazardous waste)
- Limit the allowable content of mercury present as impurities in fuels and other bulk mineral materials (UNEP 2002)

- At the international level, two multilateral environmental agreements (MEAs) exist that are of relevance to mercury and mercury compounds: Basel Convention on Control of Transboundary Movements of Hazardous Wastes and their Disposal
  - 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.

- 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.

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National initiatives

- 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.

- 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.

- 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 indication of their status of implementation, based on information submitted for this report.

- Mercury is banned in measuring devices in some EU countries: Sweden, Norway, Denmark, France (Ruzickova 2005)

	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	

TYPE AND AIM OF MEASURE	STATE OF IMPLEMENTATION
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

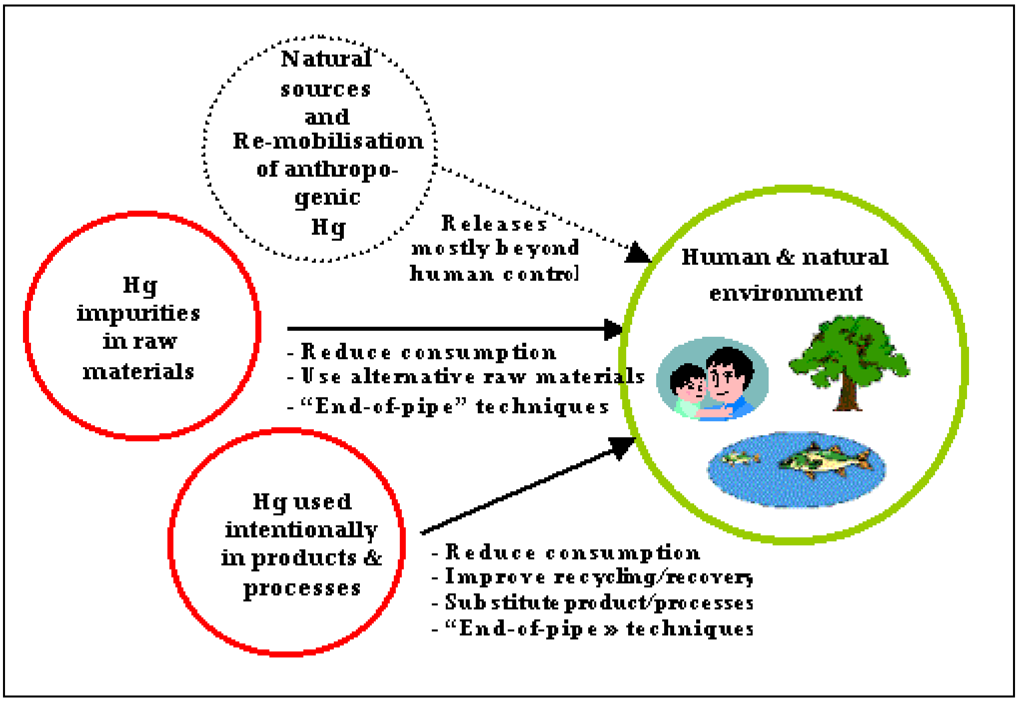
- It is also apparent that because of mercury's persistence in the environment and the fact that it is transported over long distances by air and water, crossing borders and often accumulating in the food chain far from it's original point of release, a number of countries have concluded that national 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.

Voluntary Initiatives

- 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. For example:
  (a) Promotion of voluntary commitments among producers of mercury containing products to take responsibility for ensuring appropriate handling and waste treatment of their products (for example, through information and training of users, product take-back schemes, etc.);
  (b) Promotion of voluntary commitments among users of mercury containing products (for example, hospitals) to reduce or eliminate use and limit or avoid releases of mercury into the environment through appropriate handling and waste treatment;
  (c) Promotion of voluntary reduction programmes within different private sector industries or activities to reduce and/or eliminate their uses and releases of mercury, thus stimulating the sector to identify and implement appropriate and effective solutions (UNEP 2002)

CHAPTER 7 CONCLUSIONS

- The figure below shows mercury release categories with main types of possible control mechanisms.



(UNEP 2002)

- A number of countries have identified 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.