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

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

Regional and international initiatives

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

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

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

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

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

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

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

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

CHAPTER 10 – Data gaps

National research and information needs

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

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

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

Data gaps of a general, global character

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

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

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

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

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

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

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

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

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

3 Toxicology

3.1 Overview

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

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

Methylmercury

197. 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.

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

Elemental mercury and inorganic mercury compounds

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

200. Neurological and behavioral disorders in humans have been observed following inhalation of elemental mercury vapour. Specific symptoms include tremors, emotional lability, insomnia, memory loss, neuromuscular changes, and headaches. In addition, there are effects on the kidney and thyroid.

High exposures have also resulted in death. With regard to carcinogenicity, the overall evaluation, according to IARC (1993), is that metallic mercury and inorganic mercury compounds are not classifiable as to carcinogenicity to humans (group 3). A critical effect on which risk assessment could be based is therefore the neurotoxic effects, for example the induction of tremor. The effects on the kidneys (the renal tubule) should also be considered; they are the key endpoint in exposure to inorganic mercury compounds. The effect may well be reversible, but as the exposure to the general population tends to be continuous, the effect may still be relevant.

Summary of effect levels

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

202. Other adverse effects have been seen in humans with less reliability or at much higher exposures. For methylmercury, effects have been seen on the adult nervous system, on cardiovascular disease, on cancer incidence and on genotoxicity. Also, effects have been reported on heart rate variability and blood pressure in 7 year-old children exposed prenatally, and on cardiovascular mortality in adults. For elemental mercury and inorganic mercury compounds, effects have been seen on: the excretion of low molecular weight proteins; on enzymes associated with thyroid function; on spontaneous abortion rates; genotoxicity; respiratory system; gastrointestinal (digestion) system; liver; immune system; and the skin. Several detailed evaluations of response as a function of exposure that have been conducted are reviewed in Chapter 4. As this report presents the toxicity of mercury in summary only, the reviews, which the presentation was based on, have not been checked in the original references for correct quoting during the preparation of this report.

Dietary considerations

203. 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.

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

Explanation of some of the medical terms used in this chapter

Albuminuria: Albuminuria is a form of proteinuria.

Anaemia: Condition in which the number of red blood cells per unit volume of blood is decreased from normal, resulting in decreased oxygen-carrying capacity of the blood.

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.

Atrophy of the brain: Shrinkage/loss/waste of the brain.

Cardiovascular effect: Effect on the circulatory system, comprising the heart and blood vessels.

Cerebellar ataxia: Ataxia (see above) due to disease of the cerebellum.

Cerebrovascular: Related to blood vessels of the brain.

Creatinine: A chemical waste molecule that is generated from muscle metabolism and excreted in the urine. The concentration of creatinine in serum is used as a measure for the function of the kidneys. Mercury concentrations measured in urine samples are sometimes presented on the basis of the creatinine contents in the same urine sample (µg mercury/g creatinine) – rather than per volume of urine (µg mercury/l) – in order to eliminate the variation in water contents in urine.

Cystic cavities and spongy foci: Tissue abnormality with holes and spongy areas.

Diastolic and systolic blood pressures: Diastolic blood pressure is the pressure when the heart is extending (dilating) and filled with blood. Systolic blood pressure when the heart is contracting. (A blood pressure of 140/90 means that the systolic blood pressure is 140 and the diastolic blood pressure 90).

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.

Glomerular proteinuria: Proteinuria (see below) due to dysfunction of the renal glomerulus (unit of the kidney).

Glomerulonephritis: A variety of nephritis (inflammation of the kidney) characterised by inflammation of the capillary loops in the glomeruli of the kidney. (The glomerulus is a functional unit of the kidney).

Interstitial pneumonitis: A form of pneumonia which involves the interstitial tissues (connective tissue) of the lung.

Ischemia: Local anaemia due to obstruction of the blood supply (e.g., narrowing of the arteries).

Ischemic heart disease: Heart disease because of local anaemia.

Micronuclei in peripheral lymphocytes: Small cell nucleus in the peripheral white blood cells.

Neoplastic effect: Has the effect of creating new cells that grow autonomously. A neoplasm is new and abnormal growth of tissue, which can be benign or malign (cancerous).

Nephritic/nephrotic syndrome: A disease of the kidneys that results in inflammation of the glomerulus (the portion of the kidney that filters the blood). A type of nephritis that is characterised by low serum albumin, large amount of protein in the urine and swelling (oedema).

Nephritis: Inflammation of the kidneys.

Nephrosis: Non-inflammatory, non-neoplastic disease of the kidney.

Paresthesia: An abnormal sensation, such as burning, pricking, tingling, or numbness that appears to have no objective cause.

Peripheral neuropathy: Degeneration of peripheral nerves (peripheral nerves are all nerves except the brain and the spinal cord).

Pneumonitis: Inflammation of the lungs secondary to viral or bacterial infection.

Proteinuria: More protein in the urine than normal (normal excretion is 150mg protein daily).

Renal tubule: Small structures in the kidney that filter the blood and produce the urine.

Stomatitis: Infection of the mucous membrane (the inside) of the mouth.

Tachycardia: A rapid heart rate, usually defined as greater than 100 beats per minute.

Tubular proteinuria: More protein in the urine than normal due to dysfunction of the renal tubules.