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Preparation of a global legally binding instrument on mercury

Executive summary of the document on guidance for identifying populations at risk from mercury exposure

Note by the secretariat

1. At its first session, held from 7 to 11 June 2010, the intergovernmental negotiating committee to prepare a global legally binding instrument on mercury requested the secretariat to provide the following information to it at its second session:

(a) A report on indicators to evaluate and track the health impacts of mercury and identify vulnerable populations, including the design of a sustainable awareness-raising and sensitization programme, to be developed in the context of pilot projects;

(b) Information on harmonized systems for measuring mercury body burden, starting on a pilot scale for the second session of the committee with the possibility for expansion during the remainder of the negotiation process.

2. The Chemicals Branch of the Division of Technology, Industry and Economics of the United Nations Environment Programme (UNEP) has developed, in conjunction with the World Health Organization (WHO), a document entitled "Guidance for identifying populations at risk from mercury exposure", which provides information relevant to the above requests for information. It is intended to inform countries about the potential health impacts of mercury pollution and, if necessary, to assist in identifying specific subpopulations that may be at risk. It describes approaches used to estimate exposure to mercury, including biomonitoring and methods that use data on fish consumption and mercury levels in fish. It also describes various environmental models that can be useful in predicting exposure and provides an overview of assessments of mercury exposure for some specific exposure scenarios, including occupational and other hot-spot exposures.

3. The annex to the present note contains the executive summary of the guidance document, which has been reproduced as submitted by UNEP and WHO and has not been formally edited. The full document is available in English only under the symbol UNEP(DTIE)/Hg/INC.2/INF/3.

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Annex

Guidance for identifying populations at risk from mercury exposure: executive summary

Chapter 1 - Introduction

1. The United Nations Environment Programme (UNEP) Governing Council (GC), at its 22nd session requested UNEP, in cooperation and consultation with other appropriate organizations, to facilitate and conduct technical assistance and capacity building activities to support the efforts of countries to take action regarding mercury pollution. This request was reinforced by the UNEP GC at its 23rd session in February 2005. At that session, the GC also encouraged governments to promote and improve evaluation and risk communication methods, based on, *inter alia*, guidance from the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), that will enable citizens to make health-protective dietary choices based on risk and benefit information.

2. The UNEP GC at its 24th session in February 2007 recognized that a range of activities are still required to address the challenges posed by mercury, including substitution of products and technologies; technical assistance and capacity-building; development of national policy and regulation; data collection, research and information provision, bearing in mind the need to provide assistance to developing countries and countries with economies in transition.

3. This “Guidance for Identifying Populations at Risk from Mercury Exposure” is intended to inform countries concerned about the potential health impacts of mercury pollution and, if necessary, to assist in identifying specific subpopulations that may be at risk. The document describes approaches that have been used to estimate exposure to mercury, including biomonitoring and methods that use data on fish consumption and mercury levels in fish. It also describes various environmental models that can be useful in predicting exposure to mercury. In addition, the document provides an overview of the assessment of mercury exposures for some specific exposure scenarios, including occupational and other “hot spot” exposures.

4. This document can be used as a reference for conducting research or investigations regarding mercury exposure. Depending on the nature of the research, involvement of stakeholders in various stages of the research is important, especially for local communities. This includes the process of evaluating and addressing environmental issues. For research involving biomonitoring, consultation with the community and consideration of ethical and confidentiality issues are essential.

5. Relevant reports of meetings and monographs prepared by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) were taken into account in the development of this guidance document as part of international recommendations on mercury and methylmercury in fish and other food. This document is being issued jointly by UNEP and WHO in cooperation with FAO.

Chapter 2- Background and Overview of Health Risks

Risk analysis paradigm

(a) The risk analysis paradigm described by WHO/FAO consists of three components; risk assessment, risk management and risk communication. Risk assessment and management each consist of four steps (Figure 1). The overall process is carried out under the direction of the risk manager who has been delegated the primary responsibility for managing health risks on behalf of the society. Based on preliminary information, the risk manager uses the hazard identification as the basis for deciding whether to undertake a full risk assessment in the light of other risk priorities and available resources. In regard to food safety, risk managers should be aware that the Agreement on the Application of Sanitary and Phytosanitary Measures of the World Trade Organizations requires that countries ensure that their food safety measures are based on an assessment of risks to human health taking into account the risk assessment techniques developed by the relevant international organizations, in this case FAO and WHO.

Risk assessment

(b) A human health risk assessment for chemicals is generally a study to estimate the likelihood of adverse health effects occurring in an individual, subpopulation or population due to exposure to some chemical (such as mercury). Risk assessment consists of four main steps: 1) hazard identification; 2) hazard characterization, including dose-response assessment; 3) exposure assessment; and, 4) risk characterization. Hazard identification is the review of relevant toxicological, biological, and chemical information to identify the adverse health effects associated with a pollutant under various exposure scenarios. Epidemiologic and animal studies are some of the information examined. Hazard characterization usually includes a dose-response assessment, which defines the relationship between the degree of exposure (or amount of dose) observed in animal or human studies and the magnitude of the observed adverse health effects. This usually is expressed as a quantitative measure of adverse health effects for a range of doses.

(c) In an exposure assessment, the extent, duration, frequency and magnitude of exposures to a pollutant (or multiple pollutants) are estimated via various routes (ingestion, inhalation, dermal or transplacental/in utero exposure) for individuals or populations. Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood, urine, or nails) as biomarkers or by using various mathematical models along with input data (such as facility release information, fish mercury levels, dietary patterns, etc.). Risk characterization is the integration of the hazard identification, hazard characterization, especially dose-response, and exposure assessments to describe the nature and magnitude of the health risk in a given population. Once the risk characterization is completed, the results along with other information can then be used to develop priorities, strategies and programmes to protect those populations at risk.

(d) Although the scope of the document focuses on methylmercury in fish, the principles laid out can also be applied to other contaminants in fish (such as dioxins and polychlorinated biphenyls [PCBs]). In order to do an overall risk assessment of fish contaminated with other pollutants, guidance and information for assessing these pollutants would need to be obtained from other materials and sources.

Mercury in the environment

(e) Mercury (with the chemical symbol of Hg) is a naturally occurring element found in air, water, and soil. It is distributed throughout the environment by both natural and anthropogenic (human) processes. Mercury is found in various inorganic and organic forms and is persistent in the environment. The three predominant forms include: a) elemental mercury (with the chemical symbol of Hg^0; b) ionic mercury (also known as inorganic mercury with the chemical symbol of Hg (II) or Hg^{2+}) which in nature exists as Hg (II) mercuric compounds or complexes in solution; and c) organic mercury with methylmercury (with the chemical symbol of MeHg) being the most important.

(f) In spite of its potential risks, mercury continues to be used in a variety of products and processes all over the world because of its unique properties. For example, it is the only metal that exists in liquid form at room temperature. Elemental mercury is used in artisanal and small-scale mining of gold and silver; chlor-alkali production; vinyl chloride monomer production, and in products (such as manometers for pressure measurement and control, thermometers, electrical switches, fluorescent lamp bulbs, and dental amalgam fillings). Mercury compounds are used in some batteries, pharmaceuticals, paints, and as laboratory reagents and industrial catalysts. Mercury can be released to air, water, and soils during production and uses or after disposal of the mercury-containing products and wastes. Mercury is also released during natural processes (such as volcanoes and leaching from certain soils).

(g) The UNEP 2006 report on the supply, trade, and demand of mercury reveals that demand or use of mercury is highest in small scale gold mining, followed by vinyl chloride monomer production, chlor- alkali production, and in products namely batteries, dental amalgams, measuring and control devices, lighting, electrical and electronic devices.

(h) As described in the UNEP 2002 Global Mercury Assessment, mercury is also released to the environment from various industrial sources that mobilize mercury impurities in input materials (such as fuels and feedstocks). Such sources include coal-fired power plants, non-ferrous metals smelters, and cement production plants, which are among the categories with the highest mercury emissions. These emissions lead to environmental contamination and human exposures. The degree of emissions and levels of exposures due to any one facility depends on various factors including the mercury levels in the fuel or feedstocks, emissions control devices present, stack heights, size of the operation and other factors.

Routes of exposure

(i) Mercury is a toxic, persistent pollutant that bioaccumulates and biomagnifies through food webs. People are exposed to methylmercury mainly through their diet, especially through the consumption of freshwater and marine fish and consumption of other animals that consume fish (such as marine mammals). People may be exposed to elemental or inorganic mercury through inhalation of ambient air during occupational activities, and from dental amalgams. Occupational exposures can occur where mercury or mercury compounds are produced, used in processes, or incorporated in products. Occupational exposures have been reported from (among others) chlor-alkali plants, mercury mines, mercury-based small-scale gold and silver mining, refineries, thermometer and sphygmomanometer factories, dental clinics with poor mercury handling practices, and production of mercury-based chemicals. Exposures to elemental mercury or inorganic mercury forms can also occur due to use of some skin-lightening creams and soaps, the presence of mercury in some traditional medicines, use of mercury in cultural practices, and due to various accidental mercury spills in homes, schools or other locations. Minor exposures to other forms of organic mercury may result from the use of thimerosal (ethylmercury thiosalicylate) as a preservative in some vaccines and other pharmaceuticals.

Health effects

6. All humans are exposed to some low levels of mercury. The factors that determine the occurrence and severity of adverse health effects include: the chemical form of mercury; the dose; the age or developmental stage of the person exposed (the fetus is considered to be the most susceptible); the duration of exposure; and, the route of exposure (inhalation, ingestion, and dermal contact). Dietary patterns can increase exposure to a fish-eating population when fish and seafood are contaminated with mercury.

7. The primary targets for toxicity of mercury and mercury compounds are the nervous system, the kidneys, and the cardiovascular system. It is generally accepted that developing organ systems (such as the fetal nervous system) are the most sensitive to toxic effects of mercury. Fetal brain mercury levels appear to be significantly higher than in maternal blood and the developing central nervous system of the fetus is currently regarded as the main system of concern as it demonstrates the greatest sensitivity. Other systems that may be affected include the respiratory, gastrointestinal, hematologic, immune, and reproductive systems.

8. Effects on the nervous system (especially the developing nervous system) appear to be the most sensitive toxicological endpoint observed following exposure to elemental mercury and methylmercury, while damage to the kidneys is the key end-point in exposure to inorganic mercury compounds.

Susceptible populations

9. Generally there are two susceptible subpopulations, namely, those who are more sensitive to the effects of mercury and those who are exposed to higher levels of mercury. The fetus, the newborn and children are especially susceptible to mercury exposure because of the sensitivity of the developing nervous system. In addition to *in utero* exposures, neonates can be further exposed by consuming contaminated breastmilk. Thus, new mothers, pregnant women, and women who might become pregnant should be particularly aware of the potential danger of methylmercury. Individuals with diseases of the liver, kidney, nervous system, and lung are also at higher risk of suffering from the toxic effects of mercury.

10. The other subpopulation that may be at greater risk to mercury toxicity are those exposed to higher levels of methylmercury due to fish and seafood consumption (such as recreational anglers and subsistence fishers, as well as those who regularly eat large amounts of fish and other seafood). Besides fish and shellfish, exposure can also be significant in populations consuming meat (muscle and organs) from marine mammals (such as seals and whales).

11. Individuals with dental amalgams generally have greater exposure to elemental mercury than those who do not. Other populations with potential for higher than average exposure are workers with high occupational exposure, and individuals who use various consumer products that contain mercury (such as some skin lightening creams and soaps), traditional ethnic medicines containing mercury, or use mercury for cultural and religious purposes.

Reference levels

12. Based on risk assessments and other considerations, several countries and international organizations have established reference levels for daily or weekly methylmercury or mercury intakes which, based on available data and research, are estimated to be safe (or without appreciable risk to health). The reference intake levels for methylmercury exposures range from 0.7 to 2 µg methylmercury per kilogram body weight (µg/kg body weight) per week. Reference levels have also been established to protect against inhalation of mercury metal and ingestion exposures to inorganic mercury compounds.

13. The Joint FAO/WHO Expert Committee on Food Additives (JECFA), which also evaluates chemical contaminants in the food supply, has established provisional tolerable weekly intakes (PTWIs) for total mercury at 5 µg/kg body weight and for methylmercury at 1.6 µg/kg body weight. The PTWI is the amount of a substance that can be consumed weekly over an entire lifetime without appreciable risk to health and is an end-point used for food contaminants (such as heavy metals with cumulative properties). Its value represents permissible human weekly exposure, protecting the most susceptible part of the population, to those contaminants unavoidably associated with the consumption of otherwise wholesome and nutritious foods. In the case of methylmercury, the developing fetus is considered to be the most sensitive subgroup, and neurodevelopment the most sensitive outcome.

14. The US EPA has developed Reference Doses (RfDs) for mercuric chloride of 0.3 µg/kg body weight/day and methylmercury 0.1 µg/kg body weight/day and a Reference Concentration (RfC) for elemental mercury of 0.3 µg/cubic metre. An RfD (or RfC) is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious non-cancer effects during a lifetime. It is not a direct estimator of risk but rather a reference point to gauge the potential effects. At exposures increasingly greater than the RfD (or RfC), the potential for adverse health effects increases.

15. Because fish consumption dominates the pathway for exposure to methylmercury for most human populations, many governments provide recommendations or legal limits for the maximum allowable amount of mercury and/or methylmercury in fish to be sold on the market. For example, Codex Alimentarius guideline levels are 0.5 mg methylmercury/kg in non-predatory fish and 1 mg methylmercury/kg in predatory fish. The US FDA has set an action level of 1 mg methylmercury/kg in finfish and shellfish. The European Community allows 0.5 mg mercury/kg in fishery products (with some exceptions), and Japan allows up to 0.4 mg total mercury/kg (or 0.3 mg methylmercury/kg) in fish.

16. Some governments and other organizations also provide dietary advice on the consumption of certain types and amounts of fish to help limit exposures based on consideration of both the benefits and risks of fish consumption. These advisories typically provide guidance on the amounts, types and frequency of fish consumption that is considered safe or potentially harmful for various groups (such as pregnant women and sport fishermen).

Risk characterization

17. Risk characterization is the culminating step of the risk assessment process. It integrates information from the hazard identification, dose-response, and exposure assessments and synthesizes an overall description about the potential risks. The risk characterization is intended to inform risk managers and other audiences about the outcome of the risk assessment. It also presents the variability, uncertainties and limitations of the hazard characterization and exposure assessment. Risk characterization provides a summary of the risk assessment, which can be used along with other appropriate information to inform risk managers as they consider risk management options. The implications of risk characterization of methylmercury in fish are discussed further in Chapter 7 where guidance to risk managers is provided.

Chapter 3: Estimating Exposure Through Biomonitoring

18. Approaches to estimate exposures to mercury include measuring mercury levels in hair, blood, and urine, which are considered forms of "biomonitoring". Measurements of mercury levels in these tissues can be excellent indicators of various types of mercury exposures, but the validity, usefulness, and meaning of such measurements depend on the form of mercury exposures, type of tissue measurement, and other factors.

19. This chapter describes various protocol considerations, including sampling methods, questionnaires, health assessments, and tissue measurements (Annexes A,B,C,D,E,F). A study must be well designed to provide scientifically valid results. Selection of a representative sample is essential, and good histories (such as medical, occupational, family, dietary information) and health assessments (such as neurological tests) can be important components in a study of a population which is subject to mercury exposure. All sources of mercury exposure should be identified to the extent feasible. Various ethical issues also need to be taken into account.

Selecting a study population

20. In order to select a representative sample, it is important to understand the socio-economic and demographic situation of the community. Obtaining a statistically representative sample of the community is usually the preferred approach. One important decision to consider is the number and type of individuals to be included in the study. The sample size chosen is likely to be based on various factors including costs, statistical power, staff, study facilities, and other factors. The sampling process can be random, judgmental, or possibly based on other approaches.

Biological markers

21. Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood urine, or nails). These measurements of pollutants and/or their metabolites, also known as biological markers (or biomarkers), are useful as tools for human exposure assessment, and as surveillance tools for monitoring mercury exposure in individuals and populations. There is a well-established relationship between several biomarkers of mercury exposure and adverse health effects.

22. In assessing the appropriateness of a particular biomarker of exposure, it is important to consider several factors: (1) how well the biomarker correlates with the dose (or external exposure) to various forms of mercury: (2) how well the biomarker correlates with the mercury concentration in the target tissue; (3) how well the variability over time in the biomarker correlates with changes in the effective dose at the target tissue over time; (4) what type of biomarker would be the most appropriate given the cultural characteristics of the population; (5) what kind of technology is available for collection of samples and mercury measurement; and, (6) invasiveness of the procedure in sample collection. The following biological media can be used as biomarkers for mercury exposure in humans: hair, blood, cord blood and cord tissue, urine, nails and human milk.

23. Analysing mercury in biological samples is complicated by the different organic and inorganic forms of the metal that may be present. Therefore, all forms of mercury in the sample are usually reduced to their elemental state prior to analysis. Samples must be gathered using clean, proper equipment and techniques to avoid contamination and sample loss. Some specific techniques are described for the various biological tissues.

24. A number of analytical methods are available to determine mercury concentration, and the selection of a particular analytical method depends on various factors (such as analytical regulations and guidelines of each country, detection limits, laboratory skills, availability of analytical equipment, precision needed, and whether or not speciation of mercury forms is desired). Whatever analytical method will be used, it is important to practice careful quality control/quality assurance of the obtained data, including simultaneous determination of suitable certified reference materials.

25. The presence of mercury in blood indicates recent or current exposure to mercury. There is a direct relationship between mercury concentrations in human blood and consumption of fish contaminated with methylmercury. Cord blood and cord tissue can also be considered as a biomarker sample that is worthwhile collecting if information on recent exposure is sought. The presence of mercury in urine generally represents exposure to inorganic and/or elemental mercury, and collection is non-invasive. Urine mercury levels are usually considered the best measure of recent exposures to

inorganic mercury or elemental mercury vapour because urinary mercury is thought to indicate most closely the mercury levels present in the kidneys. Environmental studies have used human milk to evaluate maternal exposure to various chemicals and examine potential exposures for breast-feeding infants.

26. Even though both blood and hair can be used to document methylmercury exposure, hair is generally the preferred choice as it provides a simple, integrative, and non-invasive sample. Once incorporated in the hair, mercury does not return to the blood, thus it provides a good long-term marker of exposure to methylmercury. Most mercury in hair is in the form methylmercury, especially among populations that consume fish. Hair incorporates methylmercury during its formation and shows a relatively direct relationship with blood mercury levels, providing an accurate and reliable method to measure methylmercury intake levels.

27. Once mercury levels are measured in a body compartment (such as blood, hair, or urine), the approximate average daily dose (or exposure level) can be calculated by using various extrapolation or conversion factors. However, limitations, uncertainties and population variabilities in using these extrapolation factors should be kept in mind when doing such conversions. Nonetheless, the quantitative relationship between mercury levels in hair and blood and daily average dose (or intake) levels of mercury (especially methylmercury) are fairly well understood. For example, a daily average methylmercury intake of 0.1 microgram per kg body weight per day (0.1 µg /kg per day) by a pregnant woman is estimated to result in hair mercury concentrations of roughly about 1 µg /g, cord blood levels of about 5 to 6 µg /L and blood mercury concentrations of about 4 to 5 µg /L. This relationship is generally linear, or directly proportional.

Examples of biomonitoring studies

28. Mercury exposures of numerous populations have been monitored by measuring mercury in blood, hair, and urine. Some of these exposure levels have been associated with human health effects and used to estimate tolerable daily intakes. Some of the most well known biomonitoring studies are in populations in Amazonian riparian communities, the Faroe Islands, and the Seychelles Islands. A number of other studies in various Arctic countries have measured mercury levels in body tissues in human populations. Mercury levels in environmental media (such as sediment, air, water, and fish) have also been measured in various studies.

29. The table below provides information on various studies conducted showing biomarkers of exposure to mercury and methylmercury among various populations in different countries.

Table: Studies of biomarkers of exposure to mercury and methylmercury*

Country	Matrix	Population	Elevated intake of fish?	Concentration of total mercury	Reference
Brazil	hair	Indigenous children aged 7-12 years Indigenous women aged 14-44 years	Yes Yes	14.45 µg/g 15.7 µg/g	Oliviera Santos et al. (2002)
Canada	hair	Indigenous	Yes	4.4 µg/g	Muckle et al. (2001)
China	hair	Representative	No	0.42 µg/g	Feng et al. (1998)
Germany	urine	Representative	No	0.4-2.0 mg/l	Becker et al. (2003)
Japan	hair	Representative	Yes	1.76-3.37 µg/g	Yasutake et al. (2003)
Spain	hair,	Children	No	0.8 µg/g	Batista et al. (1996)
Spain	blood	Representative	Yes	11-22 ng/g	Sanzo et al. (2001)
Sweden	hair & blood	Pregnant women	Yes	0.35 µg/g (hair) 1.3 µg/l (cord blood)	Bjornberg et al. (2003)
UK	hair	Pregnant women	No	0.19 µg/g	Lindlow et al. (2003)
USA	hair	Representative	No	0.3 µg/g	Pelizzari et al. (1999)
USA	blood	Women aged 16-49 years	No	1.2 µg/l	Schober et al. (2003)
USA	hair	Women aged 15-45 years	No	0.4 µg/g	Smith et al. (1997)
USA	hair	Indigenous	Yes	0.83 µg/g	Gerstenberger et al. (1997)
USA	blood	Representative of high end fish consumers	Yes	14.5 µg/l	Hightower and Moore (2003)
USA	hair	Children (1-5 yrs) Women (16-49 yrs)	No	0.12 µg/g 0.20 µg/g	McDowell et al. (2004)

* Adapted from WHO, 2004

30. Several biological sample collection and handling protocols are given in Appendix C of this document, along with sample documentation forms as examples.

Chapter 4: Exposure Assessment of Methylmercury in Fish

31. Risk analysis consists of a process comprised of three distinct but interrelated components, namely, risk assessment, risk management and risk communication. In the case of methylmercury, all three components are important to achieve consumer protection and assure the benefits of fish consumption for consumers. Hazard characterization of mercury includes the establishment of a reference level, which describes the level of exposure that is likely to be without harm.

32. In this chapter, exposure assessment is considered as this is perhaps the most important aspect for a national food safety authority. While reference levels are considered “portable” in that they generally apply to all populations, exposure of populations may be highly variable depending on their consumption patterns and on the levels of a particular chemical in food as consumed.

General approach

33. Estimating exposure to methylmercury in fish can be used as a cost-effective tool by risk managers to assess the risk of methylmercury to susceptible populations, but broader health benefits, as well as the social, cultural and economic considerations of fish consumption, need to be kept in mind when considering risk management options.

34. Mercury is an ubiquitous contaminant, even in the absence of local/regional point sources of contamination. As described in Chapter 2, the general population is primarily exposed to methylmercury through the diet, especially from fish. Levels of mercury are generally much higher in fish and marine mammals, (such as seals and some whales, than in other foods or drinking water). In predatory marine fish, about 90 % of the mercury exists in the methylated form (methylmercury), but the ratio is lower in freshwater fish.

35. However, all fish consumers are exposed to some methylmercury. Both marine and freshwater fish, as well as marine mammals, accumulate methylmercury in their muscle tissue. Moreover, methylmercury biomagnifies through the food web, meaning that apical predators, that is carnivorous species feeding at the top of the food chain, tend to have higher levels of methylmercury. Also the larger (older) individuals tend to have higher contents. Methylmercury in fish is bound to tissue protein rather than in fatty deposits; therefore, trimming and skinning of mercury-contaminated fish does not reduce the mercury content of the fillet portion. In addition, the methylmercury level in fish is not reduced by cooking.

36. Because most of the mercury in fish is methylmercury (at least for predatory marine fish) and most (greater than 95 %) of the methylmercury in fish ingested is readily absorbed into the body through the gastrointestinal tract, exposure to methylmercury (or intake) can be estimated if information is available on the following: a) types (that is, species) and amounts (such as frequency and serving size) of fish ingested per unit time (such as day or week); b) total mercury concentrations in the types of fish ingested; and, c) the body weight of persons consuming the fish.

37. Using the above information, the methylmercury intake for individuals or populations can be calculated by the following basic equation:

$$\frac{\text{Amount of fish ingested per week (kg/week)} \; * \; \text{Mercury concentration in the fish ingested } (\mu\text{g/kg})}{\text{Kilogram body weight (kg bw)}} = \text{Methylmercury intake per kilogram body weight per week } (\mu\text{g methylmercury per kg body weight per week})$$

Screening methods

38. In order to best use resources, risk managers may employ a tiered approach for assessing exposure. A tiered approach allows organizations to limit more detailed assessments to critical subpopulations that may have higher exposures or that might be more susceptible to lower levels of exposure, (such as pregnant women and children).

39. Simple screening methods are used as an initial exposure estimate. These methods sometimes result in significant overestimates of the actual exposure, depending on the input data used and assumptions used in the assessment. Therefore, if an estimated intake of the chemical substance is below its reference level, there is generally no need for more refined assessments. However, if a screening assessment result exceeds the reference level, further investigation may be warranted.

40. A screening assessment can also be used initially to estimate exposures among the general population and to help determine specific subgroups of the population considered most likely to be exposed to elevated levels of methylmercury. A process is presented in this chapter to perform increasingly refined assessments of exposures to by refining consumption estimates of fish and seafood and/or refining methylmercury concentration estimates.

Refinements to consumption estimates

41. Refinements to estimating exposures for a specific population or subgroup follow the same general principles as screening-level exposure assessment, but are more complicated and require more data. In these cases, more detailed information is gathered and evaluated on the distribution of individual fish consumption patterns among the population, especially susceptible groups. Consumption data are then integrated with the data on mercury concentrations in fish commonly consumed to estimate the exposures in the subpopulations of concern. This can be best done through national dietary surveys of individuals, but purchase data and fish market sales can also be helpful.

Refinements to concentration estimates

42. For most countries, the main source of human exposure to methylmercury is through the consumption of fish. However, levels of methylmercury vary among different fish species. For example, piscivorous fish (i.e., fish that eat other fish), also called predatory fish, are more likely to contain higher levels of methylmercury in their muscles and other tissues. Other factors that influence mercury levels in the fish include age, size, weight, and length of the fish. In addition, the environmental characteristics of the water body (such as local contamination, pH, reduction-oxidation potential, and other factors) can affect levels of mercury in the fish. Characterization of methylmercury levels in fish consumed by a population or subpopulation of interest can be obtained from existing databases in the country or region of interest. The use of surrogate data from an assemblage of the different data sets can also be used in preliminary estimates of exposures to mercury.

Exposure estimates of subpopulations

43. Estimating exposure to mercury for target subpopulations potentially at risk may require gathering new data (such as the species of fish consumed by the subpopulations, including fish sourced from markets, and the determination of methylmercury levels in those fish). In a micro-scale assessment or a site-specific assessment, fish consumption rates among a surveyed population are combined with specific measurements of mercury concentrations in the local fish actually consumed to estimate the exposure levels for the population. Depending on the type of data collected, mercury exposures can sometimes be estimated for individuals and/or subgroups among the surveyed population.

Chapter 5: Environmental Exposure Models

44. Mercury partitioning and movement in the environment is complex and depends on many environmental parameters. However, computer models can be used to predict the environmental fate and transport of emitted mercury and to estimate levels in various media and biota, and to estimate possible human exposures.

45. The chapter does not aim to give a comprehensive list of models, but provides descriptions of some available models of relevance and a few model studies with appropriate references. Several organizations are working with exposure models (such as the USEPA Center for Exposure Assessment Modelling [CEAM]). As an example, a study performed by the EU EMECAP project, estimating the exposure of inhabitants around a chlor-alkali plant is presented. However, there is still a long way to go to have precise models for estimating human exposures to mercury.

46. The use of models to estimate exposures can be a useful approach for assessing potential risks to human health. However, modelling relies on a number of assumptions with varying degrees of uncertainty, which is important to keep in mind when carrying out these types of exposure assessments.

Chapter 6: Assessment of Specific Exposure Scenarios

47. Mercury "hot spots" are defined here as regions or locations where risks of higher contamination of the environment (air, soil, water or food sources) might occur following human (anthropogenic) activities, through either increased releases or increased methylation of mercury in the environment. The most common sources of anthropogenic mercury releases include industrial activities (such as artisanal and small scale gold mining, energy production, chlor-alkali plants) and waste sites (domestic and industrial). Spills of mercury can lead to local pollution. Changes to the environment (such as deforestation or the building of reservoirs) may change the ecosystem, resulting in an increase of methylation of mercury in the environment.

48. The additional exposures resulting from a mercury "hotspot" are generally assessed by considering the direct exposures (through inhalation, ingestion and dermal) to mercury and mercury compounds, and also the indirect exposures to mercury (especially, methylmercury) via food using the methods discussed previously in Chapter 4.

Assessment of occupational exposures

49. A screening assessment should be carried out to address the likely sources of mercury exposure in the workplace. The screening assessment may include investigations of the workplace, monitoring of workplace mercury levels along with a health assessment, and, in many cases, it is also appropriate to collaborate with the local community. A workplace assessment may be done on a descriptive basis or may involve monitoring. Health assessments may determine whether signs of mercury toxicity are present, and, if warranted, may be extended to workers families and the community. Monitoring of actual exposures can be done utilizing the previously described biomonitoring tools. While workers are the primary focus of the assessment, it should be remembered that mercury contaminated clothing and other items may also result in contamination of the home environment. Following the assessment, a management plan should be developed if required to decrease occupational exposures to mercury.

Assessment of mercury "hot spots"

50. One type of mining process for gold involves mixing wet ore with metallic mercury. The mercury chemically binds with the gold or silver in the mud. The remaining mud is washed away leaving a mercury-gold (or mercury-silver) amalgam, which is then heated to release the mercury, with mostly gold and/or silver remaining. Artisanal gold mining is a major source of income in many countries, with amalgamation being the preferred extraction method. However, the process can result in high mercury exposure levels for miners and their families, and also significant environment contamination, if proper control techniques are not used.

51. Mercury is used directly in the manufacture of a number of products, and may also be released indirectly in a number of processes. Some important sources of mercury emissions are coal burning power plants, cement production, other mining activities producing mercury as a byproduct, chlor-alkali production and the manufacture of a number of products. Some of these sources may result in direct worker exposure and may also result in elevated mercury levels in the area immediately surrounding the release source, resulting in higher exposures to the population in that area.

52. Mercury-containing wastes can be generated through industrial processes or domestic use. This waste can be discarded improperly, resulting in contamination of the local area and creation of a "mercury waste site." People who live near these waste sites can be exposed to elevated levels of

mercury due to releases to the soil, air, and water. With the increased use of energy-efficient fluorescent bulbs, the disposal of such items posed a potentially serious source of mercury contamination. Although the amount of mercury used in each bulb is small, the cumulative impact of the disposal of millions of such bulbs in the future needs to be addressed by national and municipal governments.

53. Another source of environmental contamination results from mining wastes, particularly historical tailing wastes where cyanide had been used in addition to mercury to extract gold. Releases from waste sites may contaminate local fish species, resulting in elevated levels of exposure to the local community.

Other exposure scenarios

54. Mercury has traditionally been used in certain religious ceremonies resulting in high levels of ambient mercury. In addition, a number of skin lightening creams, popular in many parts of the world, contain mercury, as do some folk medicines, some of which may include the direct administration of mercury.

55. Deforestation often leads to increased erosion. Deposition of soil in waterways can result in the release and methylation of mercury in these waters, leading to high levels in fish. Where forests are cleared by burning, elevated levels of mercury may be released into the environment. Populations living downstream of deforested areas may therefore be at risk from high levels of mercury in the fish.

56. Dental amalgams containing mercury have been used for more than a century to repair dental caries. Low-level mercury exposure to the patient can arise from both inhalation and ingestion. Mercury exposure also occurs to dentists and dental workers. Mercury from dental amalgams can enter the environment through dental office wastes and from air emissions from crematoriums.

57. Thimerosal is used as a preservative in multidose liquid presentations of vaccines. In the human body, thimerosal is converted to ethylmercury, which differs chemically from methylmercury. In particular, ethylmercury is very rapidly eliminated with a half life of less than a week.

58. Reservoirs can have quite elevated levels of mercury following the initial flooding, which may result in very high levels in the local fish population. These elevated levels may be observed for up to 40 years following the initial flooding.

Chapter 7: Risk Management of Methylmercury in Fish

Risk manager's decision tree

59. The chapter is intended to address potential risk of methylmercury posed by consumption of fish. Other dietary sources of methylmercury are not addressed, but are generally considered minor compared to fish. It should also be noted that inorganic mercury is a contaminant of food, but exposure is considered less important because of the lower toxicity of inorganic mercury compared to methylmercury. Therefore, inorganic mercury in food is not addressed. Some of the steps in the decision tree make use of techniques and methods described in Chapters 3 and 4. The seven steps presented here are part of a decision tree framework, which can guide risk managers in identifying populations at risk from methylmercury from fish consumption in a consistent and cost-effective manner. The approach uses increasingly detailed exposure assessments to better characterize the risk. Consequently, Chapter 7 of this document is intended to provide guidance to risk managers to better understand the risk posed by methylmercury in fish and to develop appropriate intervention strategies to minimize risk while maximizing the benefits of fish consumption.

60. **Step 1** - In the management of potential risks posed by methylmercury in fish, the first step is the evaluation of the importance of fish as a source of protein and other nutrients for the local population. Because fish are the main pathways for human exposure to methylmercury, information on fish consumption by the population can be obtained from a number of sources. This initial phase can include a preliminary survey to identify frequency and type of fish consumed by different subgroups of the population. Note that if marine mammals are consumed, their potential contribution to mercury exposure should be included in the assessment.

61. **Step 2** - Before implementing a comprehensive exposure assessment, a biomonitoring survey using human hair can be conducted to determine exposure levels to methylmercury. This will be most important for young children and women of child-bearing age consuming one or more meals per week containing fish with high mercury content and for high fish consumers. Exposure can be assessed by analysis of total mercury concentrations in composite hair samples. The use of hair is a non-invasive, relatively inexpensive and sufficiently accurate procedure for determining methylmercury exposure among fish-eating groups.

62. **Step 3** - If average mercury concentrations in composite hair samples are much lower than reference levels, no further action is required. However, if average mercury concentrations in composite samples from any group exceed those considered hazardous, or if the margin of safety is relatively narrow, hair samples from each individual can be analysed. Evaluation of individual results will identify populations at risk from methylmercury and if levels of high percentile individuals warrant, further details on exposure can be obtained as below.

63. **Step 4** - If biomonitoring results are high, exposure to total mercury due to fish consumption can be estimated for individuals of each potentially at-risk group taking into account dietary habits and total mercury levels in fish consumed. This can be conducted using a tiered approach with increasing refinement of the food consumption and concentration estimates. Consumption of fish by species, amount and frequency can be obtained through dietary consumption surveys of individuals, supplemented with other information. Determination of body mass of consumers can also be taken at that time. Average or mean total mercury levels for common types of fish consumed can be determined on composite samples or can be obtained from available data in other countries.

64. **Step 5** - Based on the above data, total mercury exposure estimates can then be calculated on a weekly per kilogram of body weight basis, which can then be compared to the PTWI for methylmercury. If exposure is below the reference level, no further action is required in regard to fish, but investigation of other sources of mercury exposure may be warranted. If exposure to total mercury is calculated to exceed the reference levels for methylmercury, analysis of composite fish samples specifically for methylmercury can be considered.

65. **Step 6** - Composite fish samples can be analysed specifically for methylmercury to refine the exposure assessment. Consideration should first be given to the type of fish normally consumed. The ratio of methylmercury to total mercury may be as low as 0.3 for freshwater non-predatory fish. However, for marine predatory fish, this step may be omitted because the ratio of methylmercury to total mercury is often around 0.9.

66. **Step 7** - Once the methylmercury level in fish is determined, a refined calculation of methylmercury exposure from fish can be performed by multiplying the fish consumption data by average methylmercury content in fish. Intake values can then be expressed on a weekly basis and can be compared to the PTWI for methylmercury. If the PTWI is exceeded, risk management interventions can be considered as below.

Option selection

67. In general, there are two strategies to reduce the public's exposure to methylmercury in fish. One makes use of public education to influence fish consumption among populations at risk, and the other uses regulatory measures to reduce levels of methylmercury in fish. Reduction of mercury in the environment by controlling emissions can also decrease exposure to methylmercury on a long-term basis.

68. Public education strategies aimed at guiding fish consumption are important for the risk management for methylmercury exposure. The ultimate goal of these strategies is to change patterns of consumption so that people at risk can continue to eat fish and enjoy its health benefits, while also reducing their exposure to methylmercury. These strategies rely on effective risk communication, which is described in more detail below.

69. Another risk management strategy is to reduce potential exposure to methylmercury through fish consists of setting maximum acceptable concentration limits. The FAO/WHO Codex Alimentarius Commission has set guideline levels for methylmercury at 1 mg/kg for large predatory fish (such as shark, swordfish, tuna and pike) and 0.5 mg/kg for non-predatory fish. Regulatory

approaches, in the case of methylmercury in fish, have limitations in terms of cost and effectiveness and may not result in sufficient exposure reductions by themselves.

Risk communication

70. Successful risk communication is a prerequisite for effective risk management. This is applicable to both public education and regulatory strategies. In regard to public education, the fundamental goal of risk communication is to provide meaningful, relevant and accurate information, in clear and understandable terms, targeted to a specific audience with regard to the risks and benefits of fish consumption and other routes of exposure to mercury.

71. In early stages of the risk communication programme, once methylmercury in fish is identified as a problem, risk communicators need to define the goals to be achieved. The at-risk groups, or target audiences, must be clearly identified. A community can be segmented and different segments can receive different messages, according to their specific needs and risks. For example, considering neurological risks to fetus, women of child bearing age, pregnant and breast-feeding women can be considered separately from other subpopulations.

72. The acceptability of the risk management measures is closely related to public perception of risk. Therefore, it is essential for risk communicators to ensure that the risk communication process reveals information about the general public's perception of the risk of mercury exposure associated with fish consumption. Experience demonstrates that, to be most effective, the strategy used for risk communication should be tailored to stakeholders' particular characteristics and concerns, for the appropriate audience, with cultural, social and economic factors considered.

73. Communication on the risk and benefits of fish consumption should involve a two-way dialogue. Risk communicators must provide external stakeholders with clear and timely information about methylmercury risks and measures to manage it. If appropriate, other pollutants (such as PCBs and dioxins) should also be addressed to the extent feasible in the risk assessment, risk management and risk communication process. Information on benefits of fish consumption must also be provided, as well as information on alternative foods, especially in regions where fish represent a main food source. This information should be communicated in a way that stakeholders can easily understand and using media that they can easily access.

Monitoring and review

74. Once implemented, the risk management option needs to be evaluated in order to determine whether it has achieved its goals. For public education, the indicator is the degree of responsiveness of the target audience to the key message. This review allows the identification of eventual adjustments or improvements that can be implemented. Risk communicators need to identify specific evaluation strategies to measure the effectiveness of their campaign.