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Matters for consideration or action by the Conference of the Parties: effectiveness evaluation

Report of the ad hoc technical expert group for effectiveness evaluation: proposed framework for the effectiveness evaluation of the Minamata Convention on Mercury

Note by the secretariat

Addendum

The annex to the present note sets out appendix I to the report of the ad hoc technical expert group for effectiveness evaluation contained in document UNEP/MC/COP.3/14. It should also be noted that additional information complementing the report of the ad hoc technical expert group can be found in document UNEP/MC/COP.3/INF/15.

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Annex

Report of the ad hoc technical expert group for effectiveness evaluation: proposed framework for the effectiveness evaluation of the Minamata Convention on Mercury

Appendix I

Technical information on monitoring

I. Introduction

1. The present appendix summarizes the work on global monitoring arrangements done by the ad hoc technical expert group for effectiveness evaluation at two meetings, held in March 2018 and April 2019, and through electronic communication. Section II begins with the identification of the categories of available comparable monitoring data that are most effective in providing information on global trends, the monitoring data for mercury levels in the environment, biotic media and vulnerable populations that could be used to assess the impact of the Minamata Convention on Mercury with respect to mercury levels and trends, and the potential and limitations of the data identified. Section III further assesses the extent to which the information reviewed meets the needs of effectiveness evaluation, identifies major gaps, outlines options for enhancing the comparability and completeness of the information, and compares those options on the basis of their cost-effectiveness, practicality, feasibility, sustainability, global coverage and regional capabilities, to identify opportunities for future enhancements to monitoring. Section IV identifies available modelling capabilities for assessing changes in global mercury levels within and across different media, and section V examines options for establishing a baseline for monitoring data and identifies sources of data that could be used for that purpose. Building on these considerations, section VI proposes arrangements for obtaining monitoring data for effectiveness evaluation.

2. A large amount of other relevant technical information on monitoring that complements the proposal in the present appendix, including an overview of available monitoring information, is available in document UNEP/MC/COP.3/INF/15.

II. Identification of monitoring information and data

A. How monitoring activities can contribute to the development of the effectiveness evaluation framework

3. In considering monitoring information and data, the ad hoc group considered the matrices mentioned in decision MC-2/10 on effectiveness evaluation: air, water, biota and humans. The group concluded that data on levels of mercury and mercury compounds in air, humans and biotic media were available or obtainable and would be comparable on a global basis. Some experts were of the opinion that data for water are also to some degree available on a global basis. The availability and comparability of the monitoring data for each matrix are discussed in the subsections below.

4. Mercury levels in the atmosphere are directly linked to emissions from the anthropogenic sources identified in the Convention. Atmospheric monitoring activities contribute to the effectiveness evaluation of the Convention by indicating whether levels of mercury in the atmosphere are increasing or decreasing owing to changes in mercury emissions, to enable models to define source-receptor relationships. Atmospheric monitoring data also contribute to the predictive capabilities of regional and global models of mercury's impact on the environment, which can also be affected by other atmospheric chemistry issues.

5. In terms of its contribution to effectiveness evaluation, human biomonitoring has the advantage of providing information on exposure to mercury from all types of sources, integrating the results of the different types of risk-reduction measures and providing information on geographical distribution, thereby enabling the identification of areas and population groups that require urgent support in terms of risk-reduction measures.

6. Biota monitoring, for its part, has the advantage of tracking changes in environmental mercury levels at the regional and global levels that indicate the ecological effects of, and human dietary exposure to, mercury.

B. Ambient air

7. Mercury levels in ambient air have been measured in some locations for a very long period, and the resulting data have contributed to the discussion on the global nature of the mercury issue. The current available data are collected by various national and global network owners using different sampling methods. It was recognized that none of the currently available data had global coverage, but that there are potentially suitable methods for obtaining such global data (as identified in *Global Mercury Assessment 2018*).[1] An overview of the existing networks is available in the resource document UNEP/MC/COP.3/INF/15.

8. There are various ways to measure atmospheric mercury; those considered potentially suitable for obtaining globally comparable data were identified and reviewed. Such methods measure:

(a) Total gaseous mercury (TGM) or gaseous elemental mercury (GEM) concentrations in air at background and impacted sites;

(b) Wet deposition.

9. TGM/GEM can be measured using active continuous monitoring and manual active and passive air sampling techniques. Active continuous monitoring is used at several sites of existing regional and global monitoring networks to determine continuous TGM/GEM concentrations, whereas manual active and passive sampling is used in locations where no monitoring infrastructure is available, and provides average TGM concentrations as a monthly (or lower frequency) average.

10. The atmospheric deposition flux of mercury is considered as the combination of wet and dry deposition of mercury to the surface. Wet deposition is measured through the collection of rain samples, and dry deposition is either mathematically inferred or measured through tree debris. Several existing long-term networks collect wet deposition samples but, owing to a lack of comparable standard procedures, dry deposition is not always measured. The amount of total mercury measured in atmospheric deposition samples is used as basis for calculating the total atmospheric deposition flux associated with a precipitation (rain or snow) event.

11. Validated atmospheric mercury models are needed to assess source-receptor relationships and evaluate the relative importance of each anthropogenic emission source in the global mass balance of mercury with changing mercury emission regimes, meteorological conditions and climate forcing. Good global coverage of monitoring data for mercury in ambient air and deposition samples is also of fundamental importance for validating those atmospheric models. Further details are provided in document UNEP/MC/COP.3/INF/15.

C. Human exposure

12. All people are exposed to mercury to some extent. In many communities worldwide, dietary consumption of fish, shellfish, marine mammals and other foods is arguably the most important source of methylmercury exposure. Exposure to elemental and inorganic mercury mainly occurs in occupational settings (including artisanal and small-scale gold mining) or via contact with products containing mercury. There remains high concern for vulnerable groups, including various indigenous populations with high dietary or occupational exposure to mercury.

13. Human biomonitoring to assess general population exposure to mercury (i.e., background level rather than “hot spot”) provides information on global trends. In the general population, assessment of prenatal exposure is recommended, because the foetus is the most vulnerable to methylmercury exposure.[2]

[1] United Nations Environment Programme, 2018. *Global Mercury Assessment 2018*. https://wedocs.unep.org/handle/20.500.11822/27579.

[2] Differing views were expressed during the commenting process, with some parties holding that there should be flexibility in monitoring in order to maximize the chances of good geographical coverage and address general populations of both males and females, including foetuses.

14. There are two main biomarkers:[3]

(a) Total mercury in maternal scalp hair (3 cm hair strand from the scalp, to measure exposure during the third trimester);

(b) Total mercury in cord blood.

15. Scalp hair is the preferable biological matrix, as it is easily available using a non-invasive method and there are no specific requirements for transportation or storage.

16. Cord blood can be an alternative matrix to hair. Inclusion of cord blood in a survey provides several additional advantages, such as providing a more reliable measure of pre-natal exposure to mercury and of the exposure of the mother to mercury, while excluding the influence of external factors (e.g., external contamination of hair by mercury, permanent hair treatment that decreases mercury in hair), and providing an alternative biological matrix to hair in locations where hair sampling is difficult owing to cultural, ethical and religious specificities.

17. There are reliable, although variable, coefficients allowing for comparability of results from mercury measurements in hair, blood and cord blood.

18. Assessment of total mercury is sufficient to characterize exposure, unless external exposure of scalp hair needs to be evaluated.

19. In addition to general population exposure, parties may conduct biomonitoring in other vulnerable populations, including the occupationally exposed, and in hot spot areas. These data can provide additional information that would be useful in effectiveness evaluation (e.g., when repeated over time in the same populations).

20. *Global Mercury Assessment 2018* identified currently available mercury exposure data in regional and national human biomonitoring programmes, longitudinal birth cohort studies and cross-sectional information for specific populations, including high-exposure groups. The assessment revealed the following:

(a) Some of the information available from regional and national human biomonitoring programmes may be comparable (depending on the ability to disaggregate data by sex and age within the programme). Such programmes are only available in a very small number of countries, primarily in the northern hemisphere. They are expensive and therefore not feasible for the sole purpose of monitoring global mercury exposure.

(b) Comparable, high-quality data exist from longitudinal birth cohort studies, including studies of groups that consume large amounts of seafood, freshwater fish and/or marine mammals. These are available only in a small number of locations, and are not globally representative.

(c) The Global Environment Facility-funded project, entitled “Develop a plan for global monitoring of human exposure to and environmental concentration of mercury” (see UNEP/MC/COP.3/INF/19) has generated comparable data in a small number of additional countries, using the World Health Organization (WHO) protocol for assessment of prenatal exposure to mercury.[4]

21. Biomonitoring of total mercury in urine is relevant for populations with high exposure to elemental and inorganic mercury but is not appropriate for assessment of methylmercury exposure. It may be useful for evaluating the impact of control actions taken by parties with respect to mercury exposure in mining communities.

22. Human biomonitoring has a number of advantages with respect to informing an effectiveness evaluation of the Minamata Convention, including:

(a) Directly addressing the fundamental question of whether enough is being done to protect human health (article 1 of the Convention);

(b) Integrating information on exposure to mercury from different sources;

(c) Integrating the effects of the range of risk-reduction measures taken.

[3] In connection with the above footnote, some parties proposed to include hair not limited to maternal hair, and blood not limited to cord blood.

[4] WHO, 2018. “Assessment of prenatal exposure to mercury: human biomonitoring survey. The first survey protocol.” http://www.euro.who.int/en/health-topics/environment-and-health/chemical-safety/publications/2018/assessment-of-prenatal-exposure-to-mercury-human-biomonitoring-survey-2018.

23. In using human biomonitoring data, it should be noted that the level of mercury in humans is affected by many confounding factors, such as fish consumption habits (species and amount), age, gender, alcohol consumption, health condition and economic status.

D. Biotic media

24. Biota samples can provide information for different outcomes. Three types of outcomes, namely human exposure, environmental health and temporal trends, are identified in relation to biota monitoring. There is enough biotic mercury data available regionally and globally to assess environmental exposure and spatial and temporal trends in many, but not all, ecosystems and biomes of geographic interest. Humans can be exposed to dietary methylmercury from fish, birds and marine mammals (fish being a major contributor, birds a minor or major contributor depending on diets and marine mammals a major contributor in certain diets).

25. The following samples from four major biomarker groups (taxa) are considered the most relevant and are most frequently used for methylmercury monitoring:

(a) Fish: muscle fillet, muscle biopsy, fin clips, blood;

(b) Sea turtles: scutes, blood, muscle;

(c) Birds: blood, feathers, eggs, muscle, egg shells and membranes, liver and kidneys;

(d) Mammals: skin, fur or hair, muscle, liver and kidneys.

26. It is recommended that muscle tissue be used to assess samples from fish and marine mammals. For birds, blood should be used for short-term data (i.e., within days of exposure); muscle or eggs should be used for medium-term data (within weeks to months of exposure) and feathers can be used for long-term data (within months to years of exposure). It is considered sufficient to assess total mercury in all tissues (assuming a methylmercury mean level greater than 80 per cent) using either wet weight or dry weight. Samples should be georeferenced, with the level of detail varying according to the objective of the sampling. Standard operating procedures are available (e.g., through national/regional monitoring programmes); however, other more universal protocols may need to be agreed on for sampling not covered by such procedures. Inter-tissue conversions are generally a feasible means of obtaining standardized, and therefore comparable, tissue mercury concentrations.

27. *Global Mercury Assessment 2018* used the biota data from the Global Biotic Mercury Synthesis (GBMS) database,[5] which includes details about each organism sampled, its sampling location and its basic ecological data. Data have been compiled from 1,095 different references, representing 119 countries, 2,781 unique locations and 458,840 mercury samples from 375,677 total individual organisms. Examples featured in the GBMS database include datasets for some geographic areas with extensive temporal and spatial information, including areas of freshwater lakes in the northern United States of America, much of Canada, and Scandinavia. These areas represent over 500,000 samples of fish mercury concentrations taken over the past 50 years of data collection – some of which are standardized to enable comparison. Further details can be found in document UNEP/MC/COP.3/INF/15.

28. To potentially explain how the temporal trends in fish mercury concentrations change under the influence of different drivers, including environmental/climate change and deposition change, a set of minimum information targets should be developed. For each location, this should include lake (or river, estuary, sea, etc.) catchment morphology, pollution deposition patterns and local pollution history. For each biota species (here exemplified by fish), minimum data should include length, weight, sex and sexual maturity. Samples (i.e., fish muscle) for determination of total mercury concentrations may also be analysed for stable isotopes (at least nitrogen and potentially carbon also) for a better understanding of the food web processes. Many of these parameters are lacking in current databases. As an example, inter-annual and intra-annual variability is often much larger than long-term trends, making it difficult to relate temporal trend changes to large environmental drivers (including deposition). The spatial variation within the temporal trend should be considered when evaluating Convention effectiveness in the years to come. To be able to document potential changes in temporal trends, within-year variability must be lowered by improving the data adjustment, including more lake data and information and collecting data from the same lake over time.

[5] For more information, see http://www.briloon.org/uploads/BRI_Documents/Mercury_Center/Publications/For%20Web%20GBMS%20Booklet%202018%20.pdf.

E. Water and soil

29. Levels of mercury and mercury compounds in water are collected in connection with water quality issues in a number of countries. These data may be useful in tracking mercury resulting from local activities that release mercury and in modelling the movement of mercury in the aquatic environment, but monitoring data from rivers and coastal areas will not provide an indication of overall global trends. Levels of mercury in ocean water, however, could be comparable on a global basis and contribute to an understanding of the global mercury cycle. These data are collected by existing networks and ad hoc research programmes but not currently through dedicated long-term monitoring programmes.

30. Soil samples can be very useful in assessing contamination of a particular site, but global comparability may not be feasible, given differences in soil types, etc. Data on the levels of mercury in sediments are very relevant for the associated levels of mercury in biotic media; however, sampling of sediment is currently not considered widespread or easily comparable on a global basis.

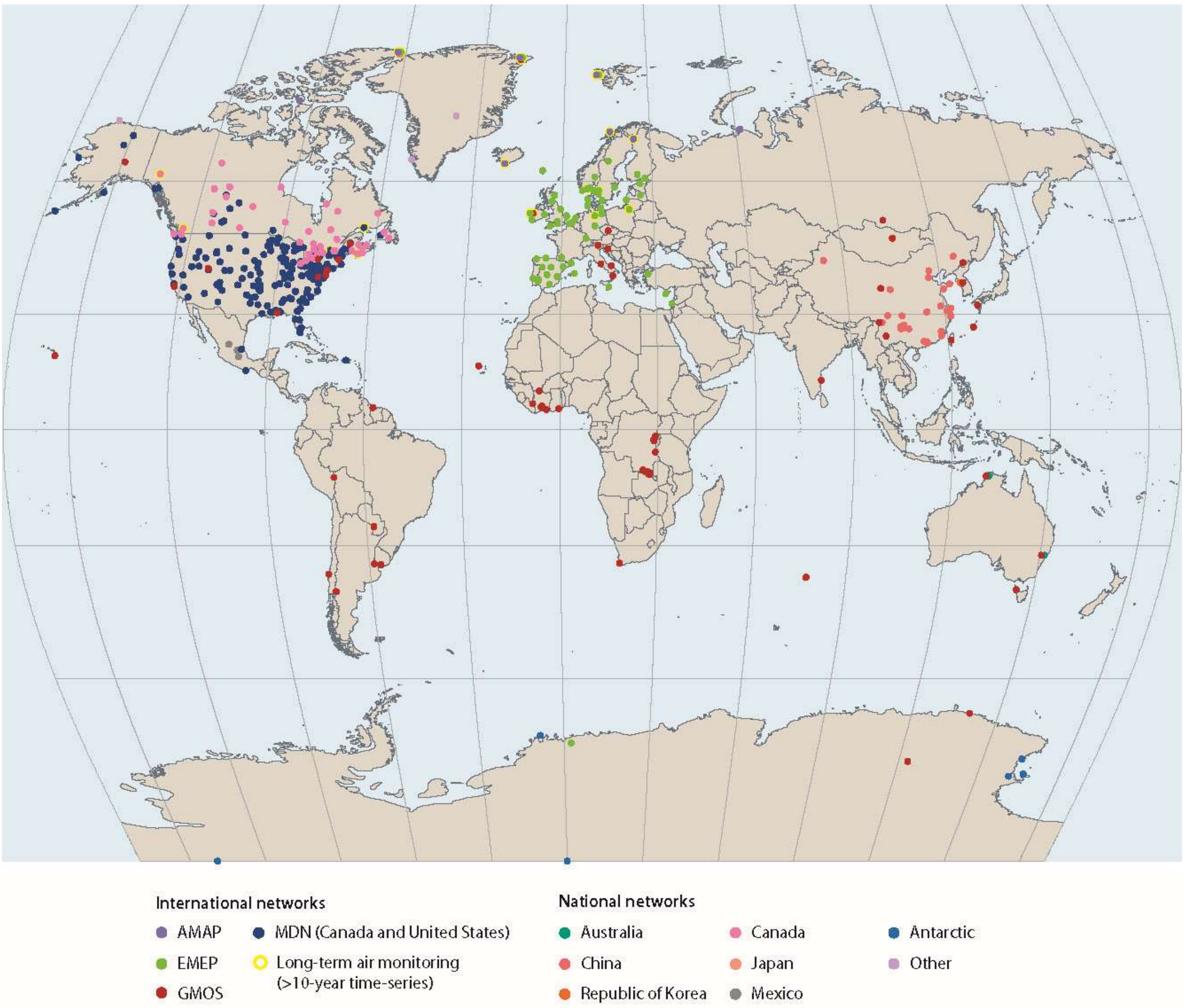
III. Comparability, gaps and options for filling gaps

A. Ambient air

31. The figure below shows current TGM/GEM monitoring efforts. From this figure, it can be seen that the gaps in TGM/GEM information could be filled by expanding the current networks that are monitoring atmospheric mercury. Such expansions would include areas within South America, Africa, the Caribbean, parts of Asia, the Russian Federation and Oceania.

Figure

Existing monitoring networks measuring mercury concentrations in air



Abbreviations: AMAP, Arctic Monitoring and Assessment Programme; EMEP, European Monitoring and Evaluation Programme; GMOS, Global Mercury Observation System; MDN, Mercury Deposition Network.

32. The following approaches are proposed for filling gaps:

(a) Couple current monitoring of TGM/GEM with new technologies (including passive and active mercury sampling);

(b) Expand current monitoring networks, where possible, to fill data gaps;

(c) Employ currently used standard procedures for data collection and treatment, where possible;

(d) Compare measurement technologies and data treatment across networks;

(e) Fill geographical data gaps using manual active or passive sampling methods;

(f) If feasible, couple manual active or passive air measurements with active and wet/dry deposition measurements;

(g) Conduct sampling at least quarterly (either averaged with active sampling data or integrated over the course of three months with passive sampling) to assess seasonal variations;

(h) When choosing new sampling sites, prioritize the filling of the information and data gaps identified in *Global Mercury Assessment 2018* and other literature.

33. It is recommended that the elaboration of future strategies aiming to fill geographical gaps in atmospheric mercury monitoring data provide for the operation of about 30 monitoring sites, with manual active or passive air sampling in each large geographical areas, such as Africa, Latin America and the Russian Federation, placed in locations that could provide information on regional/local background mercury concentrations. The suggested number of sites is only indicative; a larger number of sites using manual active or passive air sampling would certainly allow for better geographical distribution and representativeness of the regional/local emission regimes, meteorology and transport/deposition patterns. A cost analysis for air monitoring, including the proposed sampling, can be found in document UNEP/MC/COP.3/INF/15, part I, section 4.

B. Human exposure

34. Studies using the WHO protocol for assessment of prenatal exposure to methylmercury are recommended to fill the data gaps and obtain the global picture needed for effectiveness evaluation.[6] Using the WHO protocol would enable the collection of comparable data (e.g., hair samples from 250 people per study location, with minimum diversity recommended). The studies would be country-driven; local ethical clearance (i.e., that of an institutional review board) would be required, and the studies would be conducted within the national health system; therefore country approval would be a given. Each country would own its data and the submission of results would be voluntary.

35. Paragraph 1 (d) of article 17 of the Convention calls for the parties to facilitate the exchange of epidemiological information concerning health impacts associated with exposure to mercury and mercury compounds, in close cooperation with the World Health Organization and other relevant organizations, as appropriate. In line with that article of the Convention, the compilation and exchange of data on mercury levels obtained through human biomonitoring should be undertaken.

36. To facilitate the generation of globally representative human biomonitoring data and trend information, which will be most relevant for effectiveness evaluation, the monitoring group established under the global monitoring arrangements for effectiveness evaluation should be kept informed of the studies planned and carried out.

37. Data quality issues are covered by the WHO protocol. Measurement results must be analytically comparable across laboratories/studies. To ensure comparability, each national survey would need to follow the WHO-harmonized standard operating procedures for sampling and analytical methods and develop procedures for quality assurance and quality control that cover the pre-analytical phase. The availability of appropriate reference materials (samples with a certain level of mercury)[7] would support internal quality assurance. External quality assurance should be done through international inter-laboratory comparison investigations. Coordination of the studies would help to ensure appropriate quality control measures.

[6] Some parties commented that established protocols used in other human biomonitoring programmes should also be recognized.

[7] A list of existing reference materials can be found in document UNEP/MC/COP.3/INF/15, part II.

38. The WHO protocol also covers data management, analysis and evaluation issues, including whether this should be done at the national and/or international level. The protocol recommends that participating countries conduct statistical analyses at the national level and submit anonymized data to a central database for statistical analysis. The aim of a statistical analysis at the international level is to assess associations between biomarker values and predictors such as age, gender and fish consumption habits (collected via questionnaire) in a pooled dataset. The WHO protocol also addresses data communication issues, and the human health assessments of the Arctic Monitoring and Assessment Programme (AMAP) address those issues for indigenous peoples in the Artic region in particular. Communication issues include the communication of results within the country, to the individuals participating in the study and to policymakers. It should be noted that some countries may already have national guidelines relating to the communication of results.

39. The Global Environment Facility-funded project "Develop a Plan for Global Monitoring of Human Exposure to and Environmental Concentrations of Mercury" (UNEP/MC/COP.3/INF/19) has shown that the generation of data using the WHO protocol in developing countries is cost-effective, practical and feasible. The project has built local capacity to conduct the relevant studies, which can therefore be repeated over time and in a range of locations to fill gaps.

C. Biotic media

40. It has been recognized that there is a large amount of published data available on mercury levels in biota, as well as unpublished data collected for commercial and governmental purposes. It is not clear, however, to what extent published and other data reflect background information on mercury concentrations, or whether existing data emphasizes areas where high mercury concentrations are expected. As previously described, the large biotic mercury concentration datasets from the northern United States of America, Canada and Scandinavia revealed that mercury levels in freshwater fish from lakes with local mercury sources responded to regulation and management. Further evaluation work on existing data is required to gather all currently available, globally representative biotic mercury data, to assess what data are relevant, comparable and harmonizable. This process has been started with the GBMS dataset, which will allow a clearer identification of geographic and taxonomic data gaps.

41. AMAP is one of the best examples of how to operate a long-term mercury biomonitoring field programme for the benefit of both human and ecological health.[8] The Global Environment Monitoring System – Food Contamination Monitoring and Assessment Programme, commonly known as GEMS/Food, has one of the best global systems for collecting fish mercury data, through its network of collaborating centres and recognized national institutions.

D. Cost analysis

42. A table summarizing the cost, practicality, feasibility, sustainability, comparability and coverage of currently used monitoring methods for air, humans, biotic media and water is included in document UNEP/MC/COP.3/INF/15.

IV. Available modelling capabilities for assessing changes in global mercury levels within and across media

43. The table below summarizes the capabilities of models to assess changes in global mercury levels within and across media. Models for different media (air, water, land and biota) vary in their ability to simulate the movement of mercury in these media and in their state of development. Atmospheric models have been extensively evaluated and can be applied to assess spatial gradients in atmospheric mercury concentrations and deposition, as well as temporal changes, provided that high-quality, georeferenced emission data are available. By contrast, models for other media, such as land, are still mainly used in research applications. Further explanations, including reference to specific available models and a sample geographic presentation of calculations from existing models, can be found in document UNEP/MC/COP.3/INF/15.

44. Integrated modelling frameworks can illustrate the pathways by which primary releases of mercury into the atmosphere, land and water reach fish and wildlife as methylmercury, as well as the mercury exposure of some fish-consuming human populations. At present, integrated modelling

[8] AMAP, 2011. *AMAP Assessment 2011: Mercury in the Arctic*. https://www.amap.no/documents/doc/amap-assessment-2011-mercury-in-the-arctic/90; and AMAP, 2015. *AMAP Assessment 2015: Human Health in the Arctic*. https://www.amap.no/documents/doc/amap-assessment-2015-human-health-in-the-arctic/1346.

frameworks are under development and are available as a research product. Integrated models have not previously been applied or compared in global assessment efforts. A few research groups have published coupled atmosphere-ocean and atmosphere-terrestrial models in the peer-reviewed literature and, with additional model evaluation, updates should be available to begin policy-relevant analyses by 2023. Models for food web bioaccumulation of methylmercury are also available from selected groups and can be used to describe accumulation patterns at the ecosystem scale (lakes, wetlands, estuaries, contaminated sites) and for global marine food webs. The most difficult link in integrated modelling frameworks is to human exposure and health outcomes, due to the diversity of dietary preferences, food consumption patterns and individual variability in toxicokinetics affecting methylmercury uptake and elimination. All these components of integrated modelling frameworks are rapidly developing in the scientific community.

Table

Summary of available modelling capabilities for individual media

Media/availability	*Indicators needed for model input*	*Output provided*	*Gaps still to be filled*
Socioeconomic modelling: some availability Global emission models (forecasting up to 2050)	**Inputs:** socioeconomic activity data (production, population, gross domestic product), material flow and policy specifications **Evaluation:** intercomparison and past performance, anthropogenic material flow	Global demand, emission and release scenarios	Mercury emission factors to be refined (regional, site, etc.), data on mercury content of commodities to be collected, consistency across sectors and non-mercury policies to be explored (e.g., energy)
Air: widely available	**Inputs:** global emissions **Evaluation:** atmospheric measurements; wet and dry deposition data	Atmospheric concentration; deposition; temporal changes; attribution by source region	Harmonized emissions inventories to be established
Water: research product – some availability *Global oceans:* global ocean models (MITgcm, NEMO) *Estuaries (site specific); Freshwater and rivers (site specific)*	**Inputs:** spatially resolved global atmospheric Hg inputs (wet + dry) – concentrations of Hg and MeHg in rivers (globally) **Evaluation:** measured seawater total and methylmercury, and Hg^0 concentrations; These are being collected through networks (GEOTRACES, CLIVAR)	Seawater MeHg in global oceans Total Hg concentrations in seawater globally for surface and deep ocean Temporal changes	Seawater Hg species data somewhat sparse but improving Data on Hg and MeHg in global rivers largely lacking
Soils and land: research product – some availability *Global soils:* global terrestrial mercury model ASGM contaminated sites (not yet integrated into global models but would be useful)	**Inputs:** atmospheric deposition (model input) Emissions releases to land and water (very preliminary and coarse spatial resolution) Few data on runoff from contaminated sites Global land cover data and atmospheric inputs	Soil Hg concentrations globally Hg in global rivers "Hot spots" most sensitive to Hg inputs and likely to affect biota and human populations	MeHg simulation for terrestrial environments other than site-specific assessments still to be done Ground-truthing global "hot spot" analysis is needed; data on locations of ASGM and releases and/or contaminated sites to be collected

Media/availability	*Indicators needed for model input*	*Output provided*	*Gaps still to be filled*
	Evaluation: soil Hg data (good data for North America, parts of Europe)		
Biota: research product – some availability Food web bioaccumulation model for marine ecosystems (global models for plankton exist, fish under development) Food web model for freshwater ecosystems (site specific)	**Inputs:** MeHg seawater (model); Fisheries biomass production from primary productivity globally, trophic interactions (available through collaboration with NOAA/GFDL and UBC Nereus projects) **Evaluation:** Biotic mercury database Trophic level 3 for temporal trend, level 4 for spatial gradient analysis	Concentrations of MeHg in fish consumed by human populations; marine origin of MeHg Attribution of Hg sources in fish (marine mammals?) by region; Changes due to emissions and climate	Global fish model under development; could link to marine mammals/ birds Trophic level 4 data in Asia and Africa to be collected
Humans: exposure of marine fish consumers (globally) *Toxicokinetic model linking MeHg ingestion and blood and hair concentrations and outcomes* Freshwater fish and rice consumers (site-specific data, if applicable) – these may be highest risk populations Occupational exposures at ASGM sites (site specific)	**Inputs:** Biomass and MeHg concentrations in fish consumed by different subsidence populations globally (model); dietary intake data for different human populations National biomonitoring data (model evaluation)	Goal: Attribution of Hg source contributions to human populations	Mechanisms affecting relationships between external MeHg exposure and blood concentrations and outcomes for different populations are uncertain (research evolving)

Abbreviations: ASGM, artisanal and small-scale gold mining; GFDL, Geophysical Fluid Dynamics Laboratory, NOAA; Hg, mercury; MeHg, methylmercury; MITgcm, Massachusetts Institute of Technology general circulation model; NEMO, Nucleus for European Modelling of the Ocean, NOAA, United States National Oceanic and Atmospheric Administration; UBC, University of British Columbia.

V. Establishing a baseline for monitoring data

45. In the "before-after" approach, where the mercury levels before and after the implementation of the Convention are compared, monitoring data close to the beginning and the end of the evaluation period can be used. For the first effectiveness evaluation, monitoring data from before the entry into force of the Convention can be used as a baseline. For air, historical monitoring data exist for some parts of the northern hemisphere. For human biomonitoring, data from a limited number of regional and national biomonitoring programmes and longitudinal studies can be used. For biotic media, historical data on mercury levels in freshwater fish in limited geographical areas are available, and work is underway to analyse available data on ocean fish species.

46. In the "with-without" approach, to assess the change in mercury levels attributable to the measures taken to implement the Convention, mercury levels for the business-as-usual scenario need to be estimated using the integrated modelling framework described above.

VI. Proposed monitoring activities to support effectiveness evaluation

47. The review presented in the sections above shows that even though mercury has one of the largest available collective data sets among recognized environmental contaminants, data gaps remain. Parties could fill these gaps and achieve globally representative data coverage by supporting scientific activities and using already developed materials.

48. Assuming that existing mercury monitoring activities continue in a harmonized manner and are supplemented with actions to fill the gaps in data for certain regions, data on levels of mercury and mercury compounds in air, humans and biotic media either can be considered available or obtainable and would be comparable on a global basis.

49. Below is a proposal for mercury monitoring activities to be undertaken by parties, building on existing monitoring activities and knowledge, to generate data for use in the preparation of a periodic global mercury monitoring report.

A. Ambient air

50. For air monitoring, it is proposed that existing networks continue their monitoring activities, using active continuous monitoring and manual active and passive air sampling techniques to collect:

(a) Total gaseous mercury (TGM) or gaseous elemental mercury (GEM) concentrations in air at background and impacted sites;

(b) Wet deposition.

51. That information would be used to assess spatial and temporal patterns of mercury concentrations in ambient air and deposition fluxes to terrestrial and aquatic ecosystems. It should be noted that standard operating procedures suggest that mercury deposition fluxes should be monitored with samplers that are "wet only" or "bulk".

52. To fill the gaps in data for certain regions, samples should be collected monthly (or at lower frequency) to determine average regional/location background TGM concentrations, in particular in Africa, Latin America and the Russian Federation.

B. Human exposure

53. For human biomonitoring, the following biomarkers are recommended for prenatal exposure in the general population:[9]

(a) Total mercury in maternal scalp hair (3 cm hair strand from the scalp, to measure exposure during the third trimester);

(b) Total mercury in cord blood, to determine recent exposure to methylmercury.

54. It is preferable to use maternal scalp hair as a biological matrix to assess prenatal exposure. Cord blood can be an alternative matrix to hair. Human samples collected at approximately five-year intervals are feasible for human biomonitoring studies, taking into account the goal of identifying statistically significant differences and the time such studies take to implement (including adaptation of the master protocol to local circumstances, obtaining approval from local ethics bodies, training of staff, etc.). Human samples should be accompanied by information on a series of attributes (e.g., age, gender) and social and habitual information (e.g., fish consumption patterns, economic level).

55. It might be useful to coordinate sample collection with survey activities under the Stockholm Convention on Persistent Organic Pollutants to promote synergies, including coverage by a single ethics approval.

56. *Global Mercury Assessment 2018* identified currently available data on mercury exposure in national human biomonitoring programmes, longitudinal birth cohort studies and cross-sectional information for specific populations, including high-exposure groups. These activities should be continued by parties and others to provide long-term information for subsequent effectiveness evaluation.

[9] Different views were expressed in the commenting process. Some parties held that there should be flexibility in monitoring to maximize the chances of good geographical coverage and address general populations that include both males and females, including foetuses. They suggest that hair not be limited to maternal hair and that blood not be limited to cord blood.

C. Biotic media

57. For biota monitoring, an important aspect of combining monitoring efforts to document Convention effectiveness would be to minimize the effects of species-specific physiological differences by determining the proper species and tissue types to monitor. Priority should be given to the study of species that accumulate significant amounts of mercury, pose a potential risk for human health, are widely distributed over specific geographically areas and are found in numerous historical studies. In addition, there is a need to normalize or account for mercury concentrations in biota by size, age and sex, and such data should be included in the data collection process. The choice of fish species for sampling should be based on trophic level, with trophic level 4 (carnivores that eat other carnivores) being most appropriate for decisions related to human and ecological health assessments. Data on species that are commercially fished are useful for assessing the health of the general population. Other species may be important for assessing the health of indigenous peoples.

58. To account for major differences in exposure pathways, it is proposed that biotic monitoring be separated into two broad frameworks: continental and oceanic. A large quantity of relevant technical information on the frameworks is available in document UNEP/MC/COP.3/INF/15. The continental framework for mercury monitoring in biota is aimed at identifying ecosystem sensitivity spots that are able to methylate mercury and make it available in the food web. The oceanic framework covers ocean areas; the outcome combines ocean basin matrices of interest for human consumption that have global ranges to define spatial gradients (trends) of mercury levels in biotic media.