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Matters for consideration or action by the Conference of the Parties: guidance on the management of contaminated sites

Guidance on the management of contaminated sites

Note by the secretariat

1. At its first meeting, the Conference of the Parties to the Minamata Convention on Mercury considered the development of guidance in relation to the management of contaminated sites as required pursuant to paragraph 3 of article 12. In its decision MC-1/20, the Conference of the Parties requested the secretariat, drawing on previously submitted information and work undertaken in other forums and using the outline of the structure and content of the guidance agreed by the Conference of the Parties as a basis, to prepare initial draft guidance on contaminated sites and circulate it electronically to nominated experts, who were to provide comments to the secretariat.

2. The decision also indicated that the secretariat should provide a revised version of the guidance and circulate it to the experts for consideration and further electronic discussion. The initial draft guidance was made available in late March 2018, as nominations of experts were still being received. The comment phase was thus extended until the end of May. A significant number of comments were received in the early weeks of June and some were received in July. Comment submission delays and the extensive revisions resulting from the often divergent comments meant that there was insufficient time for the second commenting phase provided for in the road map for the preparation of the draft guidance. The revised draft guidance prepared taking into account the experts' comments is being submitted to the Conference of the Parties for consideration at its second meeting and for further recommendations. A decision on possible further work, taking into account the fact that only one comment phase took place in the period between the first and second meetings, is presented in annex I to this note, while the draft guidance is presented in annex II.

Suggested action by the Conference of the Parties

3. The Conference of the Parties may wish to consider the draft guidance on the management of contaminated sites and further recommendations, and to consider requesting further work on the guidance.

* UNEP/MC/COP.2/1.

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Annex I

Draft decision MC-2/[XX]: Guidance on the management of contaminated sites

The Conference of the Parties,

Recognizing the need to assist Parties in the environmentally sound management of contaminated sites through the provision of guidance,

Noting the draft guidance prepared by the secretariat in consultation with nominated experts,

Requests the secretariat:

(a) To call for additional comments on the draft guidance presented to the Conference of the Parties at its second meeting;

(b) To prepare a revised version of the draft guidance;

(c) To publish the revised draft guidance for comments by all interested stakeholders;

(d) To present the revised draft guidance to the Conference of the Parties at its third meeting for consideration and possible adoption.

Annex II

Guidance on the management of contaminated sites

Contents

A. Introduction

1. The Minamata Convention on Mercury contains provisions on the identification and management of mercury-contaminated sites, including the adoption of guidance on the management of contaminated sites by the Conference of the Parties. The present document provides guidance on the main elements of the identification and management of contaminated sites for the reference of parties who take action to manage such sites. It is intended for a range of possible users. It provides basic information on the effects of mercury, as well as guidance on managing sites, from site identification and detailed site investigation to the decision process for site management and, where appropriate, remediation. For those planning detailed management of a particular site, additional technical information can be found in the references listed at the end of the guidance.

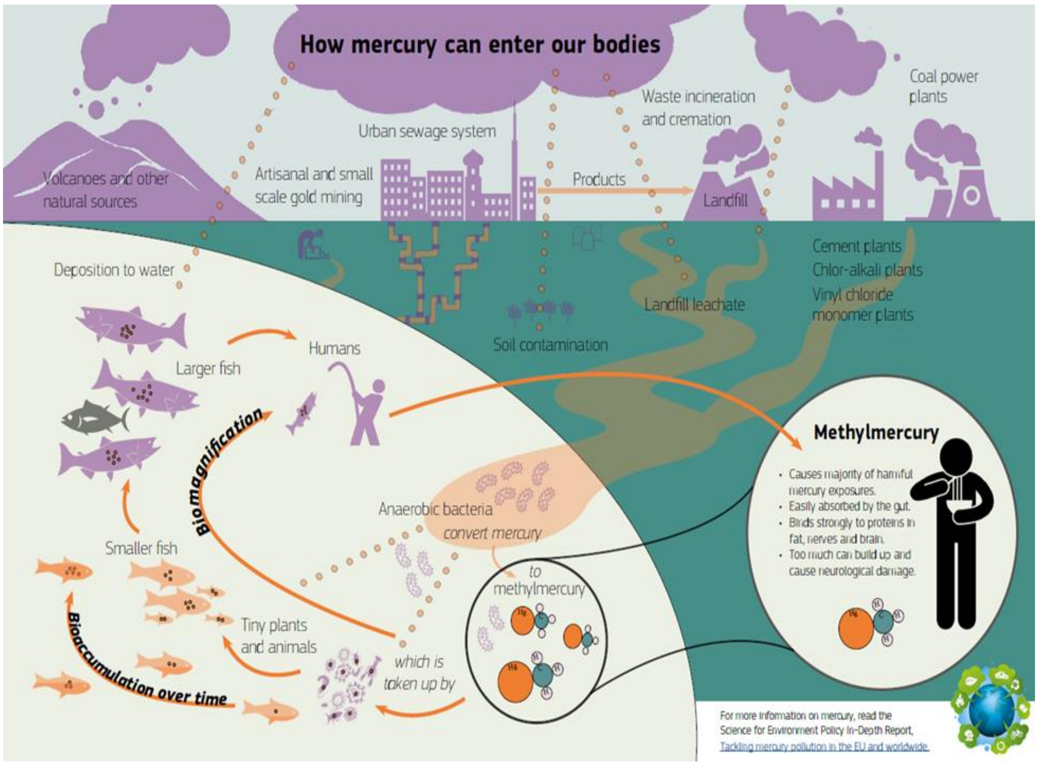
2. The guidance has been prepared in accordance with article 12 of the Convention. It does not establish mandatory requirements, nor does it attempt to add to or subtract from a party's obligations under article 12. It is recognized that, for technical, economic or legal reasons, some of the measures described in the present guidance may not be available to all parties.

Risks to human health and the environment

3. Mercury is a global threat to human health and the environment. Once released into the environment, mercury can travel long distances and persist in the environment, circulating between air, water, sediments, soil and living organisms until it is eventually removed into deep ocean sediments or mineral soils. The environmental behaviour and toxicological properties of different mercury compounds vary. Methylmercury presents the greatest risk to human health and wildlife. It is mostly produced in anaerobic aquatic ecosystems through natural bacterial process under certain conditions.

4. Mercury bioaccumulates and biomagnifies, concentrating as it moves up the food chain, so that the highest levels are found in predatory species such as tuna, marlin, swordfish, sharks, marine mammals and humans. There can be serious impacts on ecosystems, including reproductive effects on birds and predatory mammals. High acute or chronic exposure to mercury is a serious risk to human health and to the environment.

5. Effects on human health include effects on the brain, heart, kidneys, lungs and immune system of individuals of all ages. Elevated levels of methylmercury in the bloodstream of unborn babies and young children can harm the developing nervous system. Neurological and behavioural disorders in humans may be signs of significant mercury exposure, with symptoms including tremors, insomnia, memory loss, neuromuscular effects, headaches, and cognitive and motor dysfunction. In workplaces where mercury is used, people may be at risk of inhaling mercury vapour or of dermal exposure from normal work practices (in industrial, medical or dental settings or artisanal and small-scale gold mines) or from spills. For the general population, however, the most usual form of direct exposure is through consuming fish and seafood contaminated with methylmercury. Once ingested, 95 per cent of the chemical is absorbed through the gastrointestinal tract.



Global use of mercury

6. Mercury is a metal whose unique properties have led to a range of uses. A liquid at room temperature, it has been used in switches and relays, as well as measuring devices, where it enables precise determination of changes in temperature. It has been used as a catalyst in a number of industrial processes. Mercury's ability to form amalgams with other metals has led to its use in activities such as artisanal and small-scale gold mining (ASGM) and dentistry.

7. The industrial and manufacturing processes that use mercury have the potential to release mercury that could contaminate the environment. Contaminated sites pose an environmental risk in two ways: the contaminated site itself (e.g., a facility or spill site) can be a source of exposure for anyone who enters the site, and the site can be a source of mercury release to the surrounding environment. When mercury moves off site, remediation includes the removal of mercury from both the site of initial contamination and the environmental media to which it may have migrated (e.g., groundwater, surface water, sediments).

8. A wide range of mercury-added products are still produced globally, including batteries, lamps, measuring devices (such as thermometers), cosmetics and pesticides. The levels or quantity of mercury in these products is generally very low; however, mishandling of large quantities of such materials as products or waste can result in releases to the environment. Mercury amalgam is still widely used in dentistry, which can result in mercury releases to waste water from dental offices and to air from crematoria.

9. Industrial processes that use mercury either as a catalyst or as part of an electrical circuit are also still in use globally. These processes include chlor-alkali production, where very large volumes of mercury are sometimes used on site, resulting in facilities that can be heavily contaminated with mercury. Mercury has also been used in acetaldehyde production. Other industrial processes that may use mercury include vinyl chloride monomer production (for use in polyvinyl chloride), sodium or potassium methylate or ethylate production and polyurethane production. Any of these manufacturing processes has the potential to contaminate the production site as a result of the process itself, spills resulting from poor handling or accidents or mismanagement of the mercury waste generated by the process.

10. Mercury is used extensively in ASGM, where it is mixed with gold-bearing ore. The mercury binds to the gold, forming an amalgam that is then heated to release the mercury as a vapour, leaving the gold. The informal nature of many small-scale gold mining operations means that there are few, if any, controls on mercury use and release, often resulting in high levels of worker exposure and site contamination. Additionally, entire families or groups of people can be exposed to mercury vapour in the house or warehouse where processing takes place.

11. Mercury can also be emitted by a number of other industrial-scale activities where it is a contaminant in feedstock materials or a by-product of production. Examples include coal burning (in power plants and industrial boilers), non-ferrous metal smelting and roasting, cement clinker production and waste incineration. Most of this mercury can be captured through pollution control measures; however, this in turn produces mercury-contaminated solid and liquid wastes that need to be managed safely. Mismanagement of waste, particularly waste water, can result in releases of mercury to water, land and soil. Industrial-scale mining activities, particularly where the ore has a high mercury content, can also result in releases of mercury to air, land and water systems, while the mine tailings may be heavily contaminated with mercury.

Mercury emissions and releases

12. The 2013 Global Mercury Assessment indicated that the largest sources of anthropogenic emissions of mercury to air are ASGM and coal combustion (UNEP, 2013), followed by the production of ferrous and non-ferrous metals and cement production. The 2013 assessment also evaluated mercury releases to water from point sources of mercury emissions, contaminated sites and ASGM sites. The assessment found that global anthropogenic emissions of mercury to air in 2010 were estimated at 1,960 metric tons, while anthropogenic releases to water were at least 1,000 metric tons. Contaminated sites were estimated to release 8–33 metric tons of mercury per year to water and 70–95 metric tons of mercury to air, therefore contributing a relatively small amount to the global total. Other studies (Kocman and others, 2013) have found higher levels of releases to water, estimated at 67–165 metric tons of mercury per year. These figures indicate that local communities can have significant exposure to mercury from contaminated sites.

Obligations under the Minamata Convention on Mercury

13. Article 12 of the Minamata Convention sets out the following obligations with regard to contaminated sites:

> 1. Each Party shall endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds.
>
> 2. Any actions to reduce the risks posed by such sites shall be performed in an environmentally sound manner incorporating, where appropriate, an assessment of the risks to human health and the environment from the mercury or mercury compounds they contain.
>
> 3. The Conference of the Parties shall adopt guidance on managing contaminated sites that may include methods and approaches for:
>
> (a) Site identification and characterization
>
> (b) Engaging the public
>
> (c) Human health and environmental risk assessments
>
> (d) Options for managing the risks posed by contaminated sites
>
> (e) Evaluation of benefits and costs, and
>
> (f) Validation of outcomes.
>
> 4. Parties are encouraged to cooperate in developing strategies and implementing activities for identifying, assessing, prioritizing, managing and, as appropriate, remediating contaminated sites.

14. This guidance has been developed in accordance with paragraph 3 of article 12 of the Convention and is organized around the main methods and approaches listed therein. It also references national policies in a number of countries.

B. Site identification and characterization

Site identification

15. Paragraph 1 of article 12 obliges parties to endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds. This language implies development of an approach that involves a nationwide review of the extent of each party’s contaminated site problem. This will in most cases mean starting by assembling information that identifies facilities that may have engaged in manufacturing likely to result in mercury releases. As noted above, this will include both actively used and abandoned sites of manufacturing that uses

mercury or mercury compounds in its processes or products, ASGM operations, gold and other non-ferrous metals mining operations and other industrial operations. This initial identification of sites and initial estimates of the magnitude of contamination and potential for mercury release and exposure of populations will enable nations to begin prioritizing their response to their contaminated sites.

16. A first step in developing a contaminated site evaluation and management programme is to clearly define what is meant by contaminated site. The term "contaminated sites" is not specifically defined in the Convention text. The Mediterranean Action Plan guidelines on best environmental practices for environmentally sound management of mercury contaminated sites in the Mediterranean (MAPUNEP, 2015) define a contaminated site as "a place where there is an accumulation of toxic substances or residues which may affect the soil, groundwater, sediments and, in the case of mercury, even air to levels that pose a risk to the environment or human health or be above the safe limits recommended for a specific use". The World Health Organization's Regional Office for Europe defines contaminates sites as "areas hosting or having hosted human activities which have produced or might produce environmental contamination of soil, surface or groundwater, air, food-chain, resulting or being able to result in human health impacts" (WHO/EURO, 2013). Other definitions include the concept of sites where substances occur at concentrations above background levels and pose or are likely to pose an immediate or long-term hazard to human health or the environment, or where substances occur at concentrations exceeding levels specified in policies and regulations. As proposed land uses can change rapidly, consideration may need to be given to a more generic definition. Some suggest the need to define what comprises a "site", noting that a site may not necessarily be limited to a terrestrial form such as a field, a forest or a hill, but can include aquatic environments such as streams, rivers, lakes, swamps, damp-lands, estuaries and bays in cases where mercury contamination flows into water areas from, for example, ASGM sites (IPEN, 2016). As mercury is a naturally occurring element, there may be background levels of mercury that need to be taken into consideration in site characterization.

17. There seem to be two approaches to identifying potential contaminated sites: an exhaustive approach and an individual approach. The exhaustive approach starts with the implementation of a nationwide review of historical land use and the creation of an initial list of potentially contaminated sites. The list is then prioritized and the sites that require further investigation are identified. This approach can be effective when developing a comprehensive national plan for countermeasures against mercury-contaminated sites. The individual approach is based on risk management, and identifies sites that require further investigation through reviews of historical land use in cases where there is a risk of diffusing mercury contamination, such as when changing the character of the land. This approach is particularly effective and efficient when a country has performed some degree of contaminated site identification and applied environmentally appropriate management measures. For example, as contaminated sites such as properly managed waste disposal sites present no risk of contamination being diffused unless there is a need to change the land character, they do not need to be included in the targets for identification.

18. A review of the historical land use is an important aid in identifying potential contaminated sites (CCME, 2016). This can form the first step in identifying sites that may require further investigation. Until contamination has been demonstrated through site investigations, such sites can be referred to as "suspected" contaminated sites. In some jurisdictions, all proven and suspected contaminated sites are incorporated into an online database. If the status of a site changes (for example, it is demonstrated to be free of contamination), this is indicated in the database. There are a range of possible sources of site contamination, including mercury storage, manufacturing of mercury-added products, the use of mercury in manufacturing processes, mining activities (including ASGM and industrial mining activities), point sources of mercury emissions, and waste management. Sources such as the manufacturing of mercury-added products, the use of mercury in manufacturing processes and point sources of mercury emissions may include not only activities cited in the annexes to the Minamata Convention but also additional activities not controlled under the Convention. It should be noted that while there will be a primary contaminated site, there may also be associated secondary sites with contamination because of run-off, leaching or migration from the primary site. In some cases, particularly with run-off into wetlands or other sensitive ecosystems, contamination at the secondary site may consist mainly of methylmercury following bacterial transformation, or of other forms of mercury such as mercury sulphide, which may be generated through the sulphurization of mercury by sulphur content in the soil. In many countries, there may be limited knowledge of the historical uses of sites, particularly for sites where artisanal activities have been undertaken. Where possible, information on potential contaminated sites should be maintained in a database.

19. In the case of ASGM, identification of sites can be particularly problematic owing to the number of potentially contaminated sites, the informal (and sometimes illegal) nature of the activity

and the lack of formal records. It may be necessary to identify a cluster or region of sites that could be affected by artisanal mining and then work within that area to identify individual sites of concern.

20. To develop a preliminary national inventory of suspected or potential contaminated sites, government agencies can pool records of current and historical activities or land uses such as those mentioned above to form the basis for further investigation. In some jurisdictions, government agencies, businesses and private landowners are required by law[1] to notify the competent environmental authorities if they hold land that is suspected or known to be contaminated, failing which they face financial penalties.

21. In many cases, suspected contaminated sites can be initially identified by the following means (UNEP, 2015):

- Records identifying past industrial or other activities at the site
- Visual observation of the site conditions or attendant contaminant sources
- Visual observation of manufacturing or other operations known to have used or emitted a particularly hazardous contaminant
- Observed adverse effects in humans, flora or fauna possibly caused by their proximity to the site
- Physical or analytical results showing contaminant levels
- Community reports to the authorities regarding suspected releases

Site characterization

22. Once potential contaminated sites have been identified, steps should be taken to further investigate the sites that pose the greatest risk (because of factors such as location and environmental issues) to determine the contamination levels of and key risks posed by individual sites.

23. The development of a conceptual site model for the site can be a useful step. A conceptual site model is a visual representation and narrative description of the physical, chemical and biological processes occurring, or that have occurred, at a site. It should tell the story of how the site became contaminated, the extent of contamination, what media are contaminated, how the contamination was and is transported, where the contamination will ultimately end up and the population and ecosystems it may affect (CCME, 2016).[2] Consideration should be given to the chemical specificity of mercury in such a model, as well as other pollutants that may be present. Other factors that could be included are the ways that humans interact with a contaminated site, ranging from high frequency use, such as in residential areas, to lower frequency use, such as in recreational areas. The uses of groundwater from the area may also be important, and whether they are potable or non-potable uses. The conceptual site model should be updated as new information becomes available. The steps involved in developing a conceptual site model for each site could be useful for setting priorities for further investigation of particular sites. Prioritization could be based on not only sites where mercury levels are expected to be the highest but also sites that might have the greatest impact on ecosystems or populations.

24. The potentially contaminated sites identified can be further characterized through assessment protocols for both screening level assessments[3] and detailed assessments. Screening level assessment can be a useful tool for distinguishing between sites of greater and lesser concern so that resources can be focused on the most significant problems.

25. Assessment of a site should be set within the context of "investigation objectives", such as:

- Determining the site use history
- Characterizing the types of contaminants present at the site
- Determining the extent and distribution of contamination
- Developing a deeper understanding of the geology and hydrogeology of the site

[1] See, for example, Government of Western Australia, Western Australian Contaminated Sites Act 2003, Part 2, Division 1, sect.11 (3), available at https://www.legislation.wa.gov.au.

[2] Health Canada has also developed a tool for systematically developing a conceptual site model. The tool is available upon request from Health Canada's Contaminated Sites Division, via https://www.canada.ca/en/health-canada/corporate/contact-us/contaminated-sites-division.html.

[3] See, for example, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.

- Characterizing the actual migration of contaminants (fate and transport, receptors and relevant environmental and exposure pathways) and determining potential migration
- Assessing the actual exposure and potential for exposure of the local population and the environment.

26. Other investigation objectives may be set for an individual site to address specific local concerns.

27. Once the investigation objectives have been established, a sampling and analysis plan should be developed. This plan should flow from the available site information and investigation objectives. The sampling and analysis plan should include the following elements:

- Review of existing data, including identification of real and potential sources, both primary and secondary
- Pre-mobilization tasks, including preparation of a health and safety plan and location of utilities and structures that could affect or be affected by detailed investigations (this step is intended to ensure that sampling or investigation activities do not affect the health and safety of workers, bystanders or others)
- Sampling media, data types and investigation tools, including decisions about which media to sample (soil, sediment, groundwater, soil vapour, air, biota, surface water, etc.) (sampling can be used to determine such things as chemical concentration, physical properties and leachability of contaminants)
- Sampling design
- Sampling and analysis methods and quality assurance project plan

28. Any existing national site sampling and analysis protocols should be evaluated in terms of whether they are appropriate for meeting the objectives of the Convention.

29. Sampling should be designed to work towards the objectives of the assessment, which are to determine the contaminants present at the site, establish their distribution within the site and locate hotspots that can lead to unacceptable risk to human health or the environment. A sampling strategy is developed on the basis of the information collected and takes into account the conceptual site model to define the sampling pattern; density, number and distribution of sampling points, type of sampling (one stage or multi-stage), type of samples (single or composite); sampling depth (one sample should be taken very near the surface owing to the possibility of direct contact, ingestion or inhalation) and depth intervals; and the contaminants of interest (mercury, methylmercury and/or other mercury compounds). Groundwater should also be sampled whenever there is a suspicion that the water table may have been reached by the contamination or intersected during drilling of the boreholes.

30. Sampling methodologies have been considered as part of a project funded by the Global Environment Facility for the development of a plan for global monitoring of human exposure to and environmental concentrations of mercury. Standardized sampling methodologies are available, including for air (both active and passive sampling, as well as wet deposition), biota (sampling of muscle tissue for total mercury) and human biomonitoring (with the choice of matrix dependent on the type of mercury exposure experienced by the population in question). Moreover, some countries have standard sampling and analysis methods for other environmental media, such as soil. [*A reference to a soon-to-be-published report containing WHO protocols and other standardized sampling methodologies will be inserted here once it is available.*]

31. Sampling methodologies include one where land is divided into small sections and the soil in the centre of each section is sampled, and another where sampling points are determined using a conceptual site model. Depending on temperature and the container used to transport the soil samples from the sampling site to a place where they are analysed, mercury could volatilize, leading to inaccurate assessments. There is also an ISO standard for soil sampling (ISO 18400).

32. Once the assessment has established the risk, such as the presence or absence of an exposure route, it is important to prioritize the work required to manage the risk. In other words, a determination needs to be made as to whether the land requires immediate remediation or whether it would be sufficient to pay special attention to the risk of diffusing the contamination by disturbing the contaminated soil – by construction work, for example.

C. Engaging the public

33. Engaging with the public, particularly on sensitive issues such as the presence of nearby contaminated sites, is important for the successful management of issues and sites. Public engagement is often coordinated through government agencies at the local, regional or national level that have been assigned the responsibility for managing contaminated sites. There are many terms that describe the concept of "public engagement", including "public participation" "community participation", "community involvement", "community engagement", "stakeholder involvement" and "stakeholder engagement" (National Environmental Justice Advisory Council, 2013). Public consultation is an important element of sustainable remediation and is even required by legislation in certain jurisdictions. The emphasis in public engagement is to ensure that people (or groups) who could be affected by or involved or interested in an action are informed and included in the decision-making process according to their roles and responsibilities. It is therefore important to begin engaging the public early in the process of identification or detailed assessment of a contaminated site. Local knowledge can be very important for identifying potentially contaminated sites and deciding on the soil sampling strategy.

34. There are a number of elements that should be considered when setting up a public consultation process. First, effective communication, along with a two-way process of transmitting and receiving information, is important for increasing understanding among stakeholders. Scientific information should be disseminated through the most effective means for the community involved to narrow the gap between real and perceived risk. Engagement is just as important when the risks are perceived, to ensure that concerns are addressed. While there are common elements of engagement, the approach should be tailored to the specific, unique needs of the individual community. There are a number of tools and methodologies available for setting up a public consultation process.[4]

35. It is important that community members see themselves as stakeholders in the issue at hand. Community outreach should target different levels. Landowners or residents living near or on the site, communities affected by pollution from the sites and other industries in the area who might be affected by the pollution can all be considered stakeholders. Site managers and workers employed at currently active sites are also stakeholders; note, however, that if the site contamination has resulted from mishandling of mercury waste or products, for example, the source issue should be addressed before any additional action is taken. In some cases, there may be local community groups who can speak on behalf of the community as a whole or for segments of the community, such as non-governmental organizations and public health workers. In some cases, particularly where there are long-standing issues between stakeholders, it may be beneficial for consultations to be run through an independent third party (such as a consultant or an academic). Such a third party might be involved purely for the public outreach part of the process or be engaged in other activities associated with the identification or even the potential remediation of contaminated sites.

36. Quality of input should be emphasized over quantity, and engagement should be focused at least as much on gaining information from the community as on providing information to the community. It is important that the community engagement process be under way throughout the site investigation, management and/or remediation activities, as the management phase can involve significantly increased risk to adjacent communities. Excavation of contaminated materials and in-situ treatment can release dust, vapours and odours. A useful engagement mechanism can be the establishment of a community consultation committee where technical, practical and anecdotal information can be exchanged between the authorities, the site contractors and the community to ensure a shared understanding of proposed activities at the contaminated site. Such a committee can also be a useful forum for considering monitoring programmes (for vapour, dust, etc.) that might be introduced at and around the site to address community concerns during the management phase.

37. The expertise of the local community members should be recognized, as they may have the greatest knowledge and experience of the history, effects and impact of contaminated sites, as well as any changes in the effects over time. This could contribute to an understanding of what issues need to be evaluated. A comprehensive approach to the management of contaminated site is one that closely involves local community members and considers them as the focus of activities affecting the community.

38. The process of engaging the public could begin with giving information to the community involved. Information provided at this stage could include background information about the site, including information on past uses and the suspected nature of the contamination. This can be key to getting community cooperation and compliance, particularly with the initial measures that may need to

[4] See, for example, https://www.epa.gov/superfund/superfund-community-involvement-tools-and-resources.

be taken (for example, installing fencing to prevent entry to contaminated areas), as well as with site remediation activities. Ongoing activity at the site might make such engagement more difficult. Other information that should be provided includes a statement on how the community is being asked to engage, as this assists in setting common expectations for the work. An initial timeline for activities, including any deadlines for submissions or production of reports, should also be provided. The initial information can be provided through the distribution of printed material (such as flyers) directly within the community or through publication in local or community newspapers or on relevant websites. Local radio and television stations can be used to disseminate information and publicize key activities. Contact information should be provided so that those interested in obtaining further information can do so.

39. An initial plan setting out the ways in which the public will be engaged should be provided, including a timeline for the proposed engagement activities. Where inputs are being solicited, information should be provided on how the information will be collected and how it will be used. Public engagement activities can include public meetings, which may be held at central community locations, or, in some cases, at the affected site. Public meetings can have different formats, and different types of meetings may prove useful at different stages of the work. "Town hall" meetings, where key individuals speak to major discussion points followed by a question and answer session, can be useful for initial engagement, while workshop or design meeting formats can be useful at later stages to increase interaction and arrive at agreed conclusions. Consideration should also be given to creating opportunities for individuals to provide input in a confidential way, to avoid any possible pressure from facility owners or operators, particularly on workers.

40. Different methodologies for engaging with the public may be appropriate, depending on the phase of the process (site identification, investigation, remediation, aftercare, etc.). The results of the public consultation process and the decisions on future activities should be disseminated in a similar manner as the initial information at the start of the engagement process.

D. Human health and environmental risk assessments

41. The hazards of mercury are well recognized, with extensive scientific information available on the effects of exposure to mercury, including elemental mercury, inorganic mercury and methylmercury. There is, however, a need to ensure that information is available to the broader public.

42. According to the World Health Organization (WHO), elemental mercury and methylmercury are toxic to the central and peripheral nervous systems. The inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, the lungs and the kidneys, and can be fatal. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract and may induce kidney toxicity if ingested. Neurological and behavioural disorders may be observed after inhalation, ingestion or dermal exposure of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Mild, subclinical signs of central nervous system toxicity have been seen in workers exposed to an elemental mercury level in the air of 20 $\mu g/m^3$ or more for several years. Reported effects on kidneys range from increased protein in the urine to kidney failure. Permanent effects on the developing nervous system have been observed after exposure of foetuses and children, meaning that these groups are defined as being particularly vulnerable to mercury exposure (WHO, 2017).

43. The environmental effects of mercury exposure, particularly on high-level predators with potentially high dietary exposure, can include decreased reproductive success and impaired hunting ability.

44. Contaminated sites can result in locally increased levels of mercury (as well as other pollutants), which may pose risks to both humans and the environment. Drinking contaminated groundwater or surface water can result in long-term exposures, as can eating fish and seafood living in contaminated surface water. Contaminants may also be taken up by food crops grown on or near contaminated sites. Soils contaminated by mercury, especially methylmercury, can form subsurface vapour (also termed soil vapour) and subsequently migrate into overlying buildings' structures, becoming a significant source of indoor air inhalation exposure that should be considered (US DHHS), Agency for Toxic Substances and Disease Registry) Sites where exposure to mercury vapour is likely seem to be limited to those contaminated by metallic mercury, such as contaminated sites around ASGM operations.

45. Contaminated sites may result in leaching or surface runoff of mercury, which can contaminate groundwater or surface water, resulting in potential exposure to elemental or inorganic mercury through drinking water. A site's potential to contaminate either groundwater or surface water should therefore also be considered. Under anaerobic conditions, mercury may be methylated in the

environment by bacteria, particularly in sediments or other suitable environments. Methylated mercury can then enter the food chain, resulting in significant dietary exposure for predatory species, including humans. This is of particularly concern in relation to fish consumption. Several jurisdictions have established fish monitoring programmes and fish consumption advisories, especially around known, suspected or historical point sources of mercury emissions.

46. The risks associated with a particular site are related to both the level of contamination and the potential for exposure. A highly contaminated site that is isolated from population centres or that does not have significant leaching potential poses a much lower risk than a less contaminated site in an urban area or a site that is more closely linked to wetlands or with significant seepage into groundwater. Thus, site-specific clean-up targets will vary from site to site in accordance with the actual or projected exposure levels. The assessment of exposure requires consideration of both the level of mercury or mercury compounds on site and the migration of mercury off site, as well as proximity of the local population. This information may have been gathered during the process of site identification or may require additional sampling. Transfer and exposure models are available to assess the risk, and ongoing sampling should be undertaken over time to confirm that the situation is not deteriorating.

47. Depending on a site’s history, many contaminants other than mercury might be present at levels justifying national-level concern. Information on such contaminants can also be gathered during the site assessment process. The presence of other substances (including other heavy metals, persistent organic pollutants or other hazardous substances) can affect management decisions, including choices in relation to possible remediation and remediation methods and the need to adopt risk management measures such as restricting access to the site and the surrounding area.

48. Lifestyle (tobacco use, diet, etc.) can also have an impact on how contaminants affect human health; it should be noted that they tend to affect economically disadvantaged people disproportionally.

E. Options for managing the risks posed by contaminated sites

49. Following assessment of a contaminated site, decisions are needed on the most appropriate means of managing the risks presented by the site. Such decisions can be taken at the national, regional or local level or, in certain circumstances, by landowners or other entities. The objective for managing the risks should be agreed in advance of action and should be consistent with the objective of the Minamata Convention in terms of protecting human health and the environment from the anthropogenic emissions and releases of mercury and mercury compounds. The requirements for contaminated site management may be set out in national legislation and policies.

50. There are two main ways of addressing site contamination resulting from previous industrial activities or other human activities: site management and site remediation. Site management is likely to be needed as an initial step after identifying the site and possible release/exposure routes, whether or not remediation is undertaken.

51. Site management includes actions taken to reduce exposure of humans and the environment to the mercury or mercury compounds present. An ongoing or primary source of contamination to ground or surface may need to be considered.

52. The actions taken may include restricting access to the site to limit direct exposure (through fencing and warning signs) or defining restrictions on any activities that might mobilize the contamination at the site. If there is no immediate danger to the environment or the local community, it may be considered suitable to leave the contaminated material untreated until higher priority sites have been addressed. It may be possible to isolate the contamination on-site in a containment facility pending later remediation. In such circumstances, the site contamination should be periodically reviewed to ensure that mercury is not migrating off site or developing the potential to affect the environment beyond the site boundaries. Care should also be taken to keep information on soil quality and other information on the site status readily available for future users of the site.

53. Long-term monitoring could be undertaken to determine any ongoing emissions and releases related to the presence of the contaminants and their metabolites. Soil sampling is likely to provide the best indication of the level of contamination; however, monitoring could also include measuring the atmospheric levels of mercury around the site. If ground or surface water contamination is identified in the initial assessment of the site, regular water sampling may also be considered as part of the management plan.

54. Site remediation is another way of reducing the risks associated with contaminated sites. Remediation includes actions taken to remove, control, contain or reduce contaminants or exposure

pathways. The goal of remediation is to render a site acceptable and safe for its current use and also to maximize potential future uses. The decision to remediate requires consideration of a number of factors, including the desired outcome, the level of contamination, the likely exposures resulting from the contamination, the feasibility of remediation options, cost-benefit considerations, the potential adverse effects of any actions (such as environmental contamination associated with disturbing contaminated soils) and the resources available for remediation. Remediation measures should also be undertaken with due consideration for the need to carry out such activities in a sustainable manner.

55. There are a number of remediation options available, with a range of effectiveness and cost. The choice of remediation method should take into account the declared use of the site and the risks associated with that use. The presence of other contaminants may also influence the choice of remediation method. It should be noted that a remediation strategy often requires the combination of several remediation techniques to address the issue properly. Evaluating and comparing individual remedial options to determine the most effective solution is a crucial aspect of assessing the environmental and health risks associated with a contaminated site.

Soil treatment

56. When feasible, on-site treatment to either remove the contaminant or reduce the associated hazard to an acceptable level may be preferable. As far as practicable, such treatment should be carried out without adverse effects on the environment, workers, the community adjacent to the site or the broader public.

57. On-site containment of the mercury-contaminated area may be a viable option in certain circumstances. Physical barriers are used to prevent mobilization of the mercury either through the soil or to air, with covering being a cost-effective physical barrier. This may involve cutting deep trenches into the soil around the contamination and filling the trenches with slurries (such as bentonite/cement and soil mixtures). It may also involve in situ injection of stabilization chemicals into the soil using specially designed augurs. Note that such actions do not reduce the mass of mercury present, and there is potential to release contaminated material during the process (Merly and Hube, 2014). Institutional controls such as deed restrictions or land record notices could be an effective complement to measures preventing mercury mobilization.

58. Excavation and other ground-disturbing activities at the site can be conducted within temporary air-tight structures using carbon filters and negative air pressurisation. This arrangement mitigates the risk of vapour and particulate releases that could harm local communities and the environment. Such structures can also be substituted for expensive ambient air monitoring programmes, as they provide greater confidence regarding exposure levels for workers and local residents.

59. If in situ treatment of the contaminated soil to remove the contamination is not feasible, another option is to excavate the contaminated soil and remove it from the site for treatment off site. It can be sent to an approved site or storage facility for later treatment. If this option is chosen, the Party would need to ensure that any receiving facility would be able to manage the waste in accordance with the provisions of the environmentally sound management of mercury wastes, as set out in article 11 of the Convention. Off-site treatment of the excavated soil aims to either remove the contaminant or reduce the associated hazard to an acceptable level. If possible, the treated soil is then sent back to the site or to another site. Soil treatment residues would presumably contain high mercury concentrations and would need to be managed as mercury waste. Note, too, that when contaminated soil is treated and disposed of off site, the conditions of the waste management unit can have an impact on treatment effectiveness.

60. Methods that have proved successful for treating mercury-contaminated soil include solidification and stabilization, soil washing and acid extraction, thermal treatment and vitrification (US EPA, 2007), as well as electrokinetics and in situ thermal desorption. The most suitable option will depend on the level of mercury and other contaminants in the soil, their distribution and the area that is contaminated. The treatment method should therefore be selected based on the site characteristics, taking into account the technologies that are available locally and nationally.

61. The solidification process involves mixing contaminated soil or waste with a binder to create a slurry, paste or other semi-liquid state that will cure into a solid form over time (US EPA, 2007). Solidification/stabilization can be done either on or off site. This technique has been used before for clean-up and is commercially available in some countries (US EPA, 2007). Several factors affect the performance or cost of this treatment technology, including the pH of the treated substance, the presence of organic compounds, particle size, moisture content and the oxidation state of the mercury present. Examples of binding compounds include Portland cement, sulphur polymer cement, sulphide,

phosphate, cement kiln dust, polyester resins and polysiloxane compounds. These compounds vary in their effectiveness in binding mercury. Mixing of mercury with sulphur can stabilize the mercury as mercury sulphide, which reduces leachability and volatility; however, mercury sulphide can be converted back to elemental mercury under certain circumstances. A polymer stabilisation process can be undertaken, where the mercury sulphide is microencapsulated in a polymeric sulphur matrix that forms solid blocks (UNEP, 2015). This two-stage process minimizes the environmental risks from the mercury but also the possibilities for extracting the mercury at a later stage.

62. Soil washing and acid extraction can be used on contaminated soils removed from the site and treated separately. As the name suggests, soil washing is a process in which the soil is washed to remove contaminants. Soil washing and acid extraction is primarily used to treat soils with a relatively low clay content that can be separated into fractions. It is also less effective for soils with high organic content. Performance and costs may further be affected by soil homogeneity, particle size, pH and moisture content.

63. Thermal treatment is used to treat industrial and medical waste that contain mercury, but it is generally not suitable for soils with high clay or organic content. Treatment performance and costs are affected by particle size and moisture content, among other things. It is a process in which heat is used to volatilize the mercury, which can then be collected from the off-gases. It is typically done off site. Any thermal treatment undertaken needs to provide for control of the mercury vapourized by the treatment. Thermal desorption can be done either directly or indirectly. Direct desorption involves the application of heat directly to the material to be treated. Indirect thermal desorption involves heating of the exterior of a chamber, which is passed through the wall of the chamber to the material for treatment. Indirect thermal desorption has the advantage of separating the off-gases of the treated material from the combustion gases, significantly reducing the volume of contaminated gases to be filtered. The off-gases from the treated material can be treated to recover mercury through, for example, condensation processes (Environment Agency, 2012). High-temperature thermal treatment in retort ovens operating at temperatures of around 425 to 540 degrees centigrade can be used for contaminated soils with a high concentration of mercury (US EPA, 2007). Note that emissions from incineration of waste are controlled under article 8 of the Minamata Convention, and the Conference of the Parties to the Minamata Convention has adopted guidance on best available techniques and best environmental practices for controlling and, where feasible, reducing emissions of mercury and mercury compounds to the atmosphere from various sources, including waste incineration.[5]

64. Electrokinetic applications use a low-intensity current in the contaminated soil. Such technology generally involves four processes: electromigration (transport of charged chemical species in the pore fluid), electro-osmosis (transport of pore fluid), electrophoresis (movement of charged particles) and electrolysis (chemical reaction associated with electric current). While these processes can extract metals from contaminated soils, their efficiency depends on many factors. The electrokinetic process can be difficult because mercury has a low solubility in most natural soils, and the process may be inhibited by the presence of elemental mercury (Feng and others, 2015).

Water treatment technologies

65. Contaminated sites should be assessed to determine the likelihood of groundwater or surface water contamination. An assessment of hydrogeological conditions can assist in this. If mercury has been identified in water associated with a contaminated site, there are several possible treatment technologies. These include precipitation/coprecipitation, adsorption and membrane filtration (US EPA, 2007). If bottom sediments are contaminated with mercury, excavation, removal and covering may be an appropriate treatment.

66. Precipitation/coprecipitation is a commonly used treatment, but requires a wastewater treatment facility and skilled operators. Its effectiveness is affected by pH and the presence of other contaminants. The process uses chemical additives that either turn dissolved contaminants into an insoluble solid (which will then precipitate) or form insoluble solids onto which dissolved contaminants are adsorbed. The liquid is then filtered or clarified to remove the solids.

67. Adsorption (often using activated carbon) is more often used for smaller systems where mercury is the only contaminant present. This process concentrates the mercury on the surface of a sorbent, which reduces the concentration in the bulk liquid phase. Generally, the adsorption media is packed into a column through which the contaminated water is passed. The spend adsorption media will then need to be regenerated for additional use or appropriately disposed of. This process is more likely to be affected by the presence of other contaminants than other methods.

[5] http://www.mercuryconvention.org/Portals/11/documents/forms%20and%20guidance/English/BATBEP_introduction.pdf.

68. Membrane filtration is a highly effective process where the contaminants are removed from the water by passing it through a semi-permeable membrane. It is affected by other contaminants in the water, however, with suspended solids, organic compounds and other contaminants causing the membrane to work less efficiently or stop working altogether.

69. A decision to not take any immediate remediation action may allow for the development of new technologies that might make remediation more feasible in the future. In such cases, a long-term monitoring programme may be required, and a review process to consider possible future remediation could be put in place.

F. Evaluation of benefits and costs

70. All activities associated with contaminated site identification and assessment entail some level of cost. Such costs may include staff time for things like desk assessments for initial identification of possible contaminated sites and survey visits to inspect possible sites and collect samples to assess contamination levels. Sample analysis, whether through government or university laboratories or through private firms engaged to undertake the analysis, will also entail costs. There may also be private costs related to decreases in land value owing to the contamination, liability claims and reduced site functionality. The polluter-pays principle is a commonly accepted practice for covering costs. In cases where the polluter is absent or unknown, establishing a foundation can be an effective approach.

71. Public consultations may also entail costs associated with staff time or the hiring of a consultant or specialized firm.

72. Management or remediation of contaminated sites will entail costs, some of which will be one-off expenditures (capital costs) and some of which will be ongoing, such as operation, maintenance and monitoring costs. Actual costs will be very site specific and will depend on the availability of suitable technology nationally and local costs for consumables and labour.

73. The impact of mercury on the local population and the local environment also entails costs. Some of these costs are direct (such as medical care for people with adverse health effects) while others are more indirect (such as loss of income associated with contaminated fish that cannot be caught or sold, or lost cropland). The costs associated with the impact of a contaminated site on the local environment may be seen in the short or long term, but the benefits resulting from successful management of a contaminated site are seen for a very long period. Short-term costs can include the nuisance associated with remediation work, while longer-term costs can include a decrease in land value around the site and limitations on agricultural production or other land use. The costs to affected communities from non-market outcomes such as morbidity, brain damage and the loss of natural resources or clean water may be significantly higher. Such costs should be included in any economic assessments.

74. The costs associated with a number of possible remediation techniques have been assessed. Many of the available technologies have both initial capital costs and ongoing operation maintenance and monitoring costs. Parties may establish national priorities to ensure that the available funds are used effectively. Such prioritization could be built on site ranking that uses a nationally agreed scoring system to identify the highest priorities. Extensive information is available on the applicability and possible risks of some of the available technologies, while more limited information is available for other, less mature technologies.

75. Management of a site does not imply that the site no longer has an impact on the environment or human health. Restricting access to a mercury-contaminated site may limit direct exposure to humans and animals but does not necessarily prevent groundwater contamination, the migration of contaminated dust off site or atmospheric contamination from mercury vapours. All of these impacts entail costs that should be considered in any assessment.

G. Validation of outcomes

76. In order to select the most appropriate options for managing the risks associated with a contaminated site, the objectives for managing the contaminated sites must be known. It is important to be able to verify whether the actions taken have been effective in meeting those objectives. The means of verification should be established during the initial planning process, and the resources needed to undertake any necessary actions such as monitoring should be included in the overall project.

77. The objectives of a monitoring programme will vary depending on the actions selected to manage the site. Success may be measured by a reduction in on-site mercury levels, in mercury entering the environment from the site or in the exposure of populations around the site, or the return of the site to some appropriate use. If there are indications that the site management actions are not meeting the overall project objectives, further action may be required. The management cycle of planning, implementing, evaluating, taking decisions and reorganizing may need to be followed in an iterative fashion, particular when considering any future action.

78. A common form of validation is site sampling validation. For instance, if a hotspot of mercury has been excavated, sampling of the walls and base of the excavated area should show levels of mercury below the remediation objectives in terms of mercury soil concentrations. Surface water concentrations, atmospheric concentrations and levels in biota can also be measured to assess whether management and/or remediation objectives have been met.

79. As part of the overall assessment of the initial actions taken to manage a contaminated site, further action such as remediation may be considered, particularly if technology advancements make this more feasible than at the time of the initial site assessment. In any event, ongoing monitoring of soil mercury levels may be needed, even after any remediation has been done.

H. Cooperation in developing strategies and implementing activities for identifying, assessing, prioritizing, managing and, as appropriate, remediating contaminated sites

80. Cooperation between and among parties is encouraged in the Convention text, both specifically in the article on contaminated sites and within the provisions of article 14 on capacity building, technical assistance and technology transfer.

81. Cooperation could include information-sharing activities, exploration of opportunities for joint assessment of sites, coordination of communication plans in relation to sites, and other activities as considered appropriate.

82. Opportunities for information-sharing may arise during the process of identifying contaminated sites, which may also present opportunities for joint site assessment. This may be particularly appropriate where, for example, there are a number of sites within a subregion that have been previously owned or managed by the same company or where similar activities are undertaken (such as mining or chlor-alkali production).

83. Cooperative activities during the assessment of contaminated sites can generate cost savings and efficiencies, particularly if parties are able to share the costs of sampling and analysis. It may be feasible, for example, for one party to consider taking on the task of obtaining samples that are then assessed by another party with greater laboratory capacity.

84. In terms of prioritization of contaminated sites, parties may take decisions based on national priorities; however, a cooperative approach involving information sharing and joint consideration of priorities may prove useful, particularly in situations where contamination is likely to have spread across national borders. The party with the greater impact from pollution can contribute useful information to the prioritization process. Additionally, parties may wish to cooperate where there are a number of contaminated sites in close proximity, such as is likely to be seen in areas where mining activities have been undertaken. Parties may need to cooperate to restrict access to certain sites. In cases where remediation activities are planned, it may be possible to develop joint plans with regard to the treatment of contaminated material, which may provide benefits of scale or allow treatment to be undertaken at specialized facilities.

85. There are a number of long-established regulator networks on contaminated land management. At the global level, the International Committee on Contaminated Land was formed in 1993. In the European Union, member States and the European Commission have collaborated in the Common Forum on Contaminated Land since 1994, initiating two concerted actions on risk assessment and risk management.[6] These initiatives have produced guidance documents on sustainable contaminated land management that are freely available for download at http://www.iccl.ch/ and https://www.commonforum.eu/.

[6] CLARINET – Contaminated Land Rehabilitation Network for Environmental Technologies (https://www.commonforum.eu/references_clarinet.asp), and CARACAS – Concerted Action for Risk Assessment for Contaminated Sites in Europe (https://www.commonforum.eu/references_caracas.asp).

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Appendix I

Further technical information

The guidance on the management of contaminated sites has been prepared as part of the process and possible options for the management of contaminated sites in line with article 12 of the Minamata Convention on Mercury. Additional technical information is available on many of the issues covered in the guidance and may be useful to those preparing action plans or undertaking management activities.

The links in the following list of resources appear as received from stakeholders and are provided for information purposes. The list may be updated without requiring a further decision by the Conference of the Parties.

Canada

Health Canada has developed guidance on environmental and workplace health, available at https://www.canada.ca/en/health-canada/services/environmental-workplace-health/contaminated-sites/guidance-documents.html.

Information on health effects of mercury is available from Health Canada at https://www.canada.ca/en/health-canada/services/healthy-living/your-health/environment/mercury-human-health.html.

Technical information relating to drinking water guidelines is available at https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-mercury.html.

Appendix II

Framework and initial decision tree for management of contaminated sites

To be developed following the second meeting of the Conference of the Parties to the Minamata Convention on Mercury.