

# GUIDANCE ON THE MANAGEMENT OF CONTAMINATED SITES



MINAMATA  
CONVENTION  
ON MERCURY

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# NOTE BY THE SECRETARIAT

This document sets out guidance on sites contaminated by mercury or mercury compounds, as adopted by the Conference of the Parties to the Minamata Convention on Mercury at its third meeting in November 2019. Paragraph 3 of article 12 of the Minamata Convention provides that the Conference of the Parties shall adopt guidance on managing contaminated sites.

The Conference of the Parties at its first meeting in September 2017, in its decision MC-1/20, requested the secretariat to prepare draft guidance, in consultation with experts nominated by Governments and others, and to submit it to the Conference of the Parties at its second meeting.

The Conference of the Parties considered the draft at its second meeting in November 2018 and, in its decision MC-2/8, requested the secretariat to further revise the draft guidance, taking into account comments and information received from parties and stakeholders and in consultation with the nominated experts, and to submit the revised draft to the Conference of the Parties at its third meeting.

The secretariat revised the draft guidance taking into consideration the comments and information received from a number of Parties and stakeholders and posted it for further comments. The secretariat convened a teleconference of the nominated experts in July 2019 to consider the comments received, and subsequently prepared the further revised draft that was submitted to the Conference of the Parties as UNEP/MC/COP.3/8. At their teleconference, the nominated experts agreed that some of the information was too technical to be included in the guidance but should be made available to parties to support the implementation of article 12. That information was made available in document UNEP/MC/COP.3/INF/13.

The Conference of the Parties at its third meeting considered the draft guidance and adopted it with some changes in its decision MC-3/6, as presented in this document. The decision of the Conference of the Parties also included the following:

- The Conference noted the importance of capacity-building, technical assistance and technology transfer, as appropriate and in accordance with articles 13 and 14 of the Convention;
- It encouraged the Parties to take the guidance into account in identifying, assessing and managing, and, as appropriate, remediating sites contaminated by mercury or mercury compounds;
- It requests the secretariat to continue to collect technical information that supports the guidance, in cooperation with experts nominated by Governments, relevant networks and others, and to make such information available to parties;
- It notes that the guidance may need to be revised in the future in the light of experience in its use to ensure that it continues to reflect best practice.

Supplementary technical information has been posted on the Convention's website. The secretariat welcomes further information that supports Parties to implement article 12 of the Convention, including case studies and good practice.

**A**

# INTRODUCTION

# A INTRODUCTION

## 1. BACKGROUND

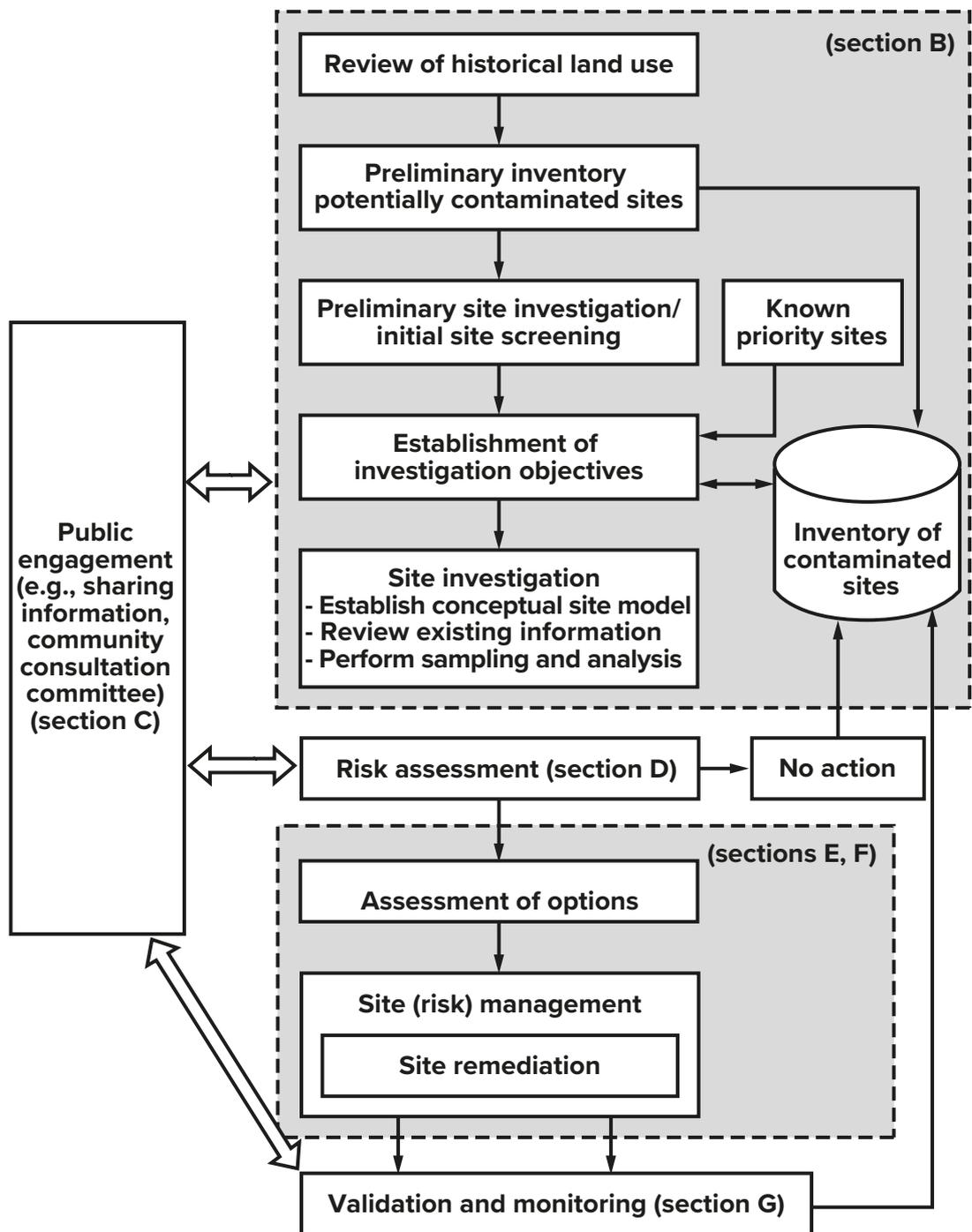
1. The Minamata Convention on Mercury contains provisions on contaminated sites, including the identification and assessment of sites and the adoption of guidance on the management of contaminated sites by the Conference of the Parties. The present document provides guidance on the main elements for the identification and management of contaminated sites to be used as reference by those parties that wish to take action to manage such sites. It is intended for a range of possible users, including government officials and practitioners. It provides guidance on managing sites, from site identification and detailed site investigation to the decision process for site management and, where appropriate, remediation. It is intended to provide general advice to parties in non-prescriptive language, taking into account the variety of national considerations, including socioeconomic circumstances and the limitations faced by parties. It takes cognisance of best environmental practices (BEP) and best available techniques (BAT). 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. Figure 1 illustrates a model decision tree for the management of contaminated sites. Each step in the decision tree is elaborated on in the indicated section of the guidance.

3. The guidance 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. Existing applicable laws and regulations that are relevant to contaminated site activities take precedence over this guidance.

4. The term "contaminated site" is not specifically defined in the Convention text. Countries may have their own definition in their legislation. In this guidance, "contaminated site" refers to a site where there is a confirmed presence, caused by human activities, of mercury and mercury compounds at such level(s) as to be considered by a party as posing a significant risk to human health or the environment.

**FIGURE 1** FRAMEWORK AND INITIAL DECISION TREE FOR THE MANAGEMENT OF CONTAMINATED SITES



## 2. RISKS TO HUMAN HEALTH AND THE ENVIRONMENT

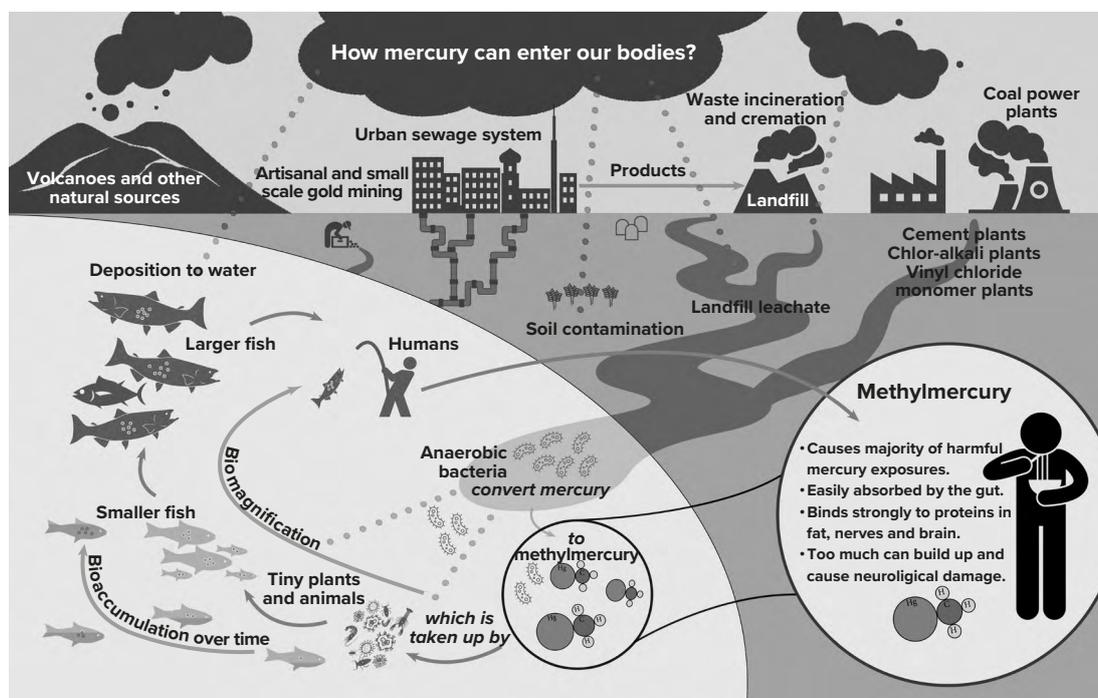
5. Mercury is a naturally occurring chemical element found in air, water and soil. Its natural background levels vary from one location to another and depend on the local geology. Mercury is emitted and released into the environment from volcanic activity and weathering of rocks and as a result of human activity. The main anthropogenic sources of mercury emissions and releases include primary mercury mining, artisanal and small-scale gold mining (ASGM) operations, coal burning, industrial processes, dental amalgam and waste incineration.

6. As depicted in figure 2, 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 deposited to deep ocean sediments or mineral soils. Mercury exists in various forms: elemental (metallic) mercury and inorganic and organic mercury compounds. The environmental behaviour and toxicological properties of different mercury compounds vary.

7. 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 ASGM) or from spills. Mercury vaporizes even at room temperature. Given that inhaled elemental mercury vapour can penetrate the central nervous system and progressively damage it, elemental mercury vapour is considered to be one of the most toxic forms of mercury.

8. For the general population, however, the most usual form of direct exposure is through consuming fish and seafood contaminated with methylmercury, one of the most toxic forms of mercury. Methylmercury 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 and mercury compounds is a serious risk to human health and the environment. Effects on human health include effects on the brain, heart, kidneys, lungs and immune system of individuals of all ages. Methylmercury has the ability to bind with fat tissue and cross the blood-brain barrier and the placental barrier. Therefore, elevated levels of methylmercury in the bloodstream of unborn babies and young children can harm the developing nervous system.

**FIGURE 2** SOURCES AND EXPOSURE PATHWAY OF MERCURY



### 3. GLOBAL USE OF MERCURY

9. Mercury is a metal whose unique properties have led to a range of uses. Liquid at room temperature, it has been used in switches and relays, as well as in measuring devices, where it enables precise determination of changes in temperature. It has been used in a number of industrial processes. Mercury's ability to form amalgams with other metals has led to its use in processes and products such as ASGM and dentistry.

10. A wide range of mercury-added products are still produced globally, including batteries, lamps, measuring devices (such as thermometers), cosmetics and pesticides. The level 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 significant mercury releases to wastewater from dental offices and to air from crematoria.

11. 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.

12. Mercury is used extensively in ASGM operations, 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 and around the house or warehouse where processing takes place.

13. It should be noted that mercury releases are not limited to those from the intentional use of mercury. Mismanagement of waste and wastewater, including from pollution control measures, can result in mercury release and contamination of soil and water. Industrial-scale mining activities where the ore has a high mercury content or where oil and gas are extracted could result in releases of mercury to land and water.

### 4. MERCURY EMISSIONS AND RELEASES FROM CONTAMINATED SITES

14. Contaminated sites pose an environmental risk in two ways: the contaminated site itself (e.g., a facility or localized 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, resulting in unacceptable risk, remediation or other risk management actions may be targeted at both the site of initial contamination and the environmental media to which it may have migrated (e.g., groundwater, surface water, sediments).

15. The 2013 Global Mercury Assessment (UNEP, 2013) evaluated, among other things, mercury releases to water from point sources of mercury emissions, contaminated sites and ASGM sites. 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. Other studies (Kocman and others, 2013) have reported higher levels of releases to water, estimated at 67–165 metric tons of mercury per year. The 2018 Global Mercury Assessment (UNEP, 2019) recognizes contaminated sites as an anthropogenic source for which emissions cannot yet be reliably estimated, and also concludes that there is no detailed knowledge on the processes of secondary releases resulting from mercury initially released to terrestrial pathways.

## 5. OBLIGATIONS UNDER THE MINAMATA CONVENTION ON MERCURY

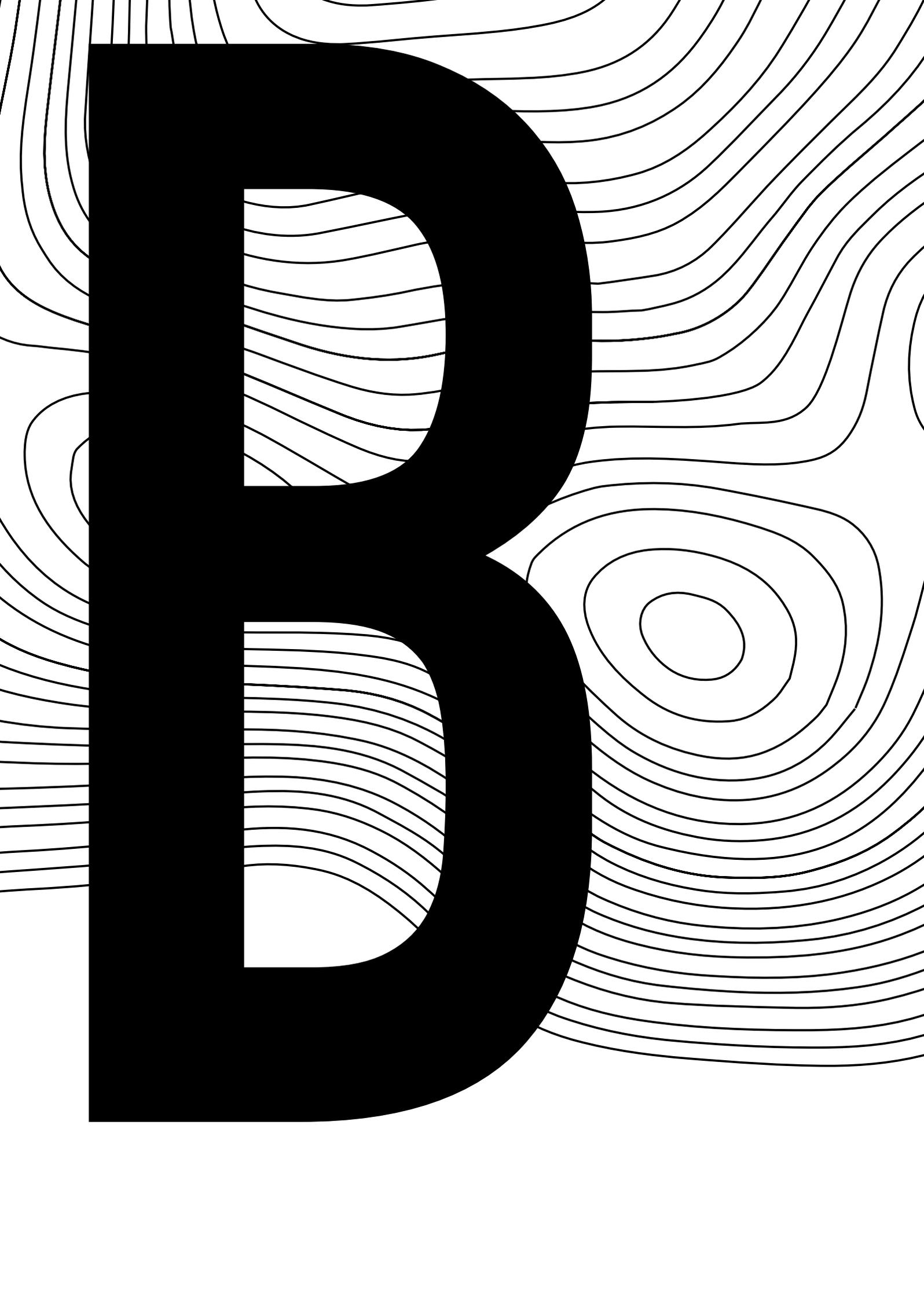
16. Article 12 of the Minamata Convention sets out the following obligations with regard to contaminated sites:

- (a) Each party shall endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds.
- (b) 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.
- (c) The Conference of the Parties shall adopt guidance on managing contaminated sites that may include methods and approaches for:
  - (i) Site identification and characterization;
  - (ii) Engaging the public;
  - (iii) Human health and environmental risk assessments;
  - (iv) Options for managing the risks posed by contaminated sites;
  - (v) Evaluation of benefits and costs;
  - (vi) Validation of outcomes.

17. In article 12, Parties are also encouraged to cooperate in developing strategies and implementing activities for identifying, assessing, prioritizing, managing and, as appropriate, remediating contaminated sites.

18. This guidance has been developed in accordance with paragraph 3 of article 12 of the Convention (para. 16 (c) above) and is organized around the main methods and approaches listed therein. It also references national policies in a number of countries.

**BB**



# SITE IDENTIFICATION AND CHARACTERIZATION

# B SITE IDENTIFICATION AND CHARACTERIZATION

## 1. SITE IDENTIFICATION

19. Paragraph 1 of article 12 obliges parties to endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds. The language used 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 to identify facilities that may have engaged in activities likely to result in mercury releases, to the extent that such identification is legally, technically and financially practicable. This could include both active and abandoned sites where mercury or mercury compounds are or have been used in processes or products, ASGM operations or other industrial operations. It may include historical mines that were not managed in accordance with modern mining standards. This initial identification of sites and initial estimates of the magnitude of contamination and potential for mercury release and exposure of populations will enable countries to begin prioritizing their response to their contaminated sites in line with existing legal frameworks, where applicable.

20. A systematic approach can be used to identify and catalogue contaminated sites, starting with a nationwide review of historical and current land use and the creation of an initial list of potentially contaminated sites. The list can then be prioritized and the sites that require further documentation and investigation identified. This can be an effective approach when developing a comprehensive national plan for addressing mercury-contaminated sites. Another approach can supplement the systematic approach by identifying individual contaminated sites when land use changes or actions such as excavation or construction take place. Although individual identification of contaminated sites is not an adequate substitute for the systematic approach, it may be appropriate for countries that have a national policy in place for managing contaminated sites.

21. A review of the historical and current land use is important in identifying potential contaminated sites (CCME, 2016). This can be 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 confirmed and suspected contaminated sites are incorporated into an online database.

22. There is a range of possible sources of site contamination, including:

- (a) Mercury storage;
- (b) Manufacturing of mercury-added products;
- (c) Use of mercury in manufacturing processes;
- (d) ASGM activities using mercury or primary ore rich in mercury in which the mercury is mobilized;
- (e) Primary mercury mining and abandoned, historical mines not managed in accordance with modern practices;
- (f) Point sources of emissions and releases;
- (g) Waste treatment and disposal;
- (h) Other sources.

23. Sources such as manufacturing of mercury-added products, use of mercury in manufacturing processes and point sources of mercury emissions and releases 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 in some cases a primary contaminated site may have associated secondary contaminated sites 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(s) may consist mainly of methylmercury following bacterial transformation, or of other forms of mercury, such as mercury sulfide, which can be generated through the sulfurization of mercury by sulfur in the soil.

24. In the case of ASGM, identification of sites can be particularly problematic due 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. Information collected for the development of a national action plan pursuant to article 7 may be useful in the identification of contaminated ASGM sites.

25. To develop a preliminary national inventory of potentially 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<sup>1</sup> to notify the competent environmental authorities if they hold land that is suspected or known to be contaminated, failing which they face financial penalties.

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

- (a) Records identifying past industrial or other activities at the site;
- (b) Visual observation of the site conditions or attendant contaminant sources;
- (c) Visual observation of manufacturing or other operations known to have used or emitted a particularly hazardous contaminant;
- (d) Observed adverse effects in humans, flora or fauna possibly caused by their proximity to the site;<sup>2</sup>
- (e) Existing physical or analytical results showing contaminant levels;
- (f) Community reports to the authorities regarding suspected releases.

## 2. INVENTORY DEVELOPMENT

27. As identification of suspected and confirmed contaminated sites within a jurisdiction progresses, it becomes possible to develop an inventory of sites that can be used to track assessment and management of individual sites over time. In this context, parties may wish to develop an inventory that would allow them to use a risk-based approach to efficiently prioritize the use of resources to protect the human populations and parts of the environment at most immediate risk of exposure to mercury from the most hazardous sites. The sites presenting the highest risk can be managed as a priority and sites that present a low risk can have resources allocated at a later point in time.

28. Inventories can act as a “living database” in the sense that (potentially) contaminated sites can be added as they are discovered (such as legacy sites that may be very old, with no records uncovered during unrelated construction work). Sites can also be removed from the inventory when shown to be free of contamination or fully remediated, although parties may choose to instead classify such sites as remediated or not contaminated and leave them in the database in case advances in science require reassessment at a later date. Such a situation could arise, for instance, if acceptable limits for a given contaminant were significantly revised downwards, rendering a remediated site “contaminated” once again if it fails to meet the new criteria.

29. Inventories can have internal classification systems to assist authorities with land use planning and development approvals and to track site assessment and management. One example used by an Australian state jurisdiction employs the following seven classifications:

- (a) Contaminated – remediation required;
- (b) Contaminated – restricted use;
- (c) Remediated for restricted use;
- (d) Possibly contaminated – investigation required;
- (e) Decontaminated;
- (f) Not contaminated – unrestricted use;
- (g) Report not substantiated.<sup>3</sup>

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<sup>1</sup> 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>.

<sup>2</sup> It should be noted that adverse effects on human health as an indicator of site contamination are likely to be identified only in cases of very high contamination or after the site has been identified as contaminated. Attribution of health effects to contaminated sites should be based on site assessment and exposure information.

<sup>3</sup> This jurisdiction allows any member of the public to report a suspected contaminated site using a standardized form and then investigates the site.

30. An innovative approach to inventory analysis is to combine inventory data with a geographical information system to provide a publicly available online database showing the location of confirmed contaminated sites.<sup>4</sup>

### 3. SITE CHARACTERIZATION

31. Once suspected contaminated sites have been identified, steps may 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.

32. The suspected contaminated sites identified can be further characterized through phased investigation. Countries may establish their priorities for site characterization based on the land use history or other indicators of contamination. Countries with significant ASGM activities or with decommissioned mercury-cell chlor-alkali plants may, for instance, choose to prioritize those sectors. Preliminary site investigation or initial site screening, which may involve site visits and a review of available information, can be a useful tool for prioritizing sites for detailed investigation.<sup>5</sup>

33. The development of a conceptual site model (CSM) for the site is an essential step in site characterization and assessment.<sup>6</sup> A CSM is a visual representation and narrative description of the physical, chemical and biological processes that may occur, are occurring or have occurred at a site. It shows the sources of contamination (potential and confirmed) and the pathways to the identified receptors (actual or future). Its specific elements can include the following (CCME, 2016):<sup>7</sup>

- (a) An overview of historical, current and planned future land uses;
- (b) A detailed description of the site and its physical setting that is used to form hypotheses about the release and ultimate fate of contamination at the site;
- (c) Sources of contamination at the site, the potential chemicals of concern and the media (soil, groundwater, surface water, sediments, soil vapour, indoor and outdoor air, locally grown foods, biota) that may be affected;
- (d) The distribution and chemical form of contaminants within each medium, including information on concentration, total amount and/or transport (flux);
- (e) How contaminants may be migrating from the source(s), the media and pathways through which migration and exposure of potential human or ecological receptors could occur, and information needed to interpret contaminant migration, such as geology, hydrogeology, hydrology and possible preferential pathways;
- (f) Information on climate and meteorological conditions that may influence contamination distribution and migration;
- (g) Where relevant, information pertinent to soil vapour intrusion into buildings, including construction features of buildings (e.g., size, age, foundation depth and type, presence of foundation cracks, entry points for utilities), building heating, ventilation and air conditioning design and operation, and subsurface utility corridors;
- (h) Information on human and ecological receptors and activity patterns at the site or at areas affected by the site.

34. It should be noted that not all the elements listed above necessarily need to be addressed. The latter elements in particular require that the technician performing the survey and the authority responsible for determining the effectiveness of the survey have a certain amount of expertise. The use of a CSM depends on each party's circumstances and site situations. Alternative methods can be used as well.

35. Investigation objectives should be established, which may broadly include:

- (a) Characterizing the types of contaminants present at the site;

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<sup>4</sup> Contaminated Sites Database of Western Australia, <https://dow.maps.arcgis.com/apps/webappviewer/index.html?id=c2ec-b74291ae4da2ac32c441819c6d47>.

<sup>5</sup> Some countries have established trigger values for screening. The United Kingdom has set levels of 1 ppm for elemental mercury in soil and 11 ppm for methylmercury (Environment Agency, 2009). The Australian national guidelines for contaminated sites (NEPC, 1999) listed 10 ppm methylmercury and 15 ppm elemental mercury as a screening level for residential property.

<sup>6</sup> ISO 21365 (2018). Soil quality - Conceptual site models for potentially contaminated sites.

<sup>7</sup> 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>.

- (b) Developing an understanding of the site geology and hydrogeology;
- (c) Delineating the extent and distribution (vertical and lateral) of contamination;
- (d) Characterizing the actual migration of contaminants and potential transformations;
- (e) Obtaining data to identify and assess potential adverse effects on public health and the environment.

36. 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:

- (a) Review of existing data, including identification of real and potential sources, both primary and secondary;
- (b) 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);
- (c) Sampling media, data types and investigation tools, including decisions about which media to sample (soil, sediment, groundwater, soil vapour, air, biota, surface water, etc.);
- (d) Sampling design;
- (e) Sampling and analysis methods and a quality assurance plan.

37. Sampling should be designed to work towards the objectives of the assessment, which are to determine the contaminants of concern present at the site and establish their distribution within the site and locate hotspots that may lead to unacceptable risk to human health or the environment. A sampling strategy is developed on the basis of the information collected. It takes into account the CSM 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 and intervals, and contaminants of concern (mercury, methylmercury and/or other mercury compounds). When determining the sampling plan, practical considerations such as logistics, sample transport and preservation, equipment availability and costs should be taken into account.

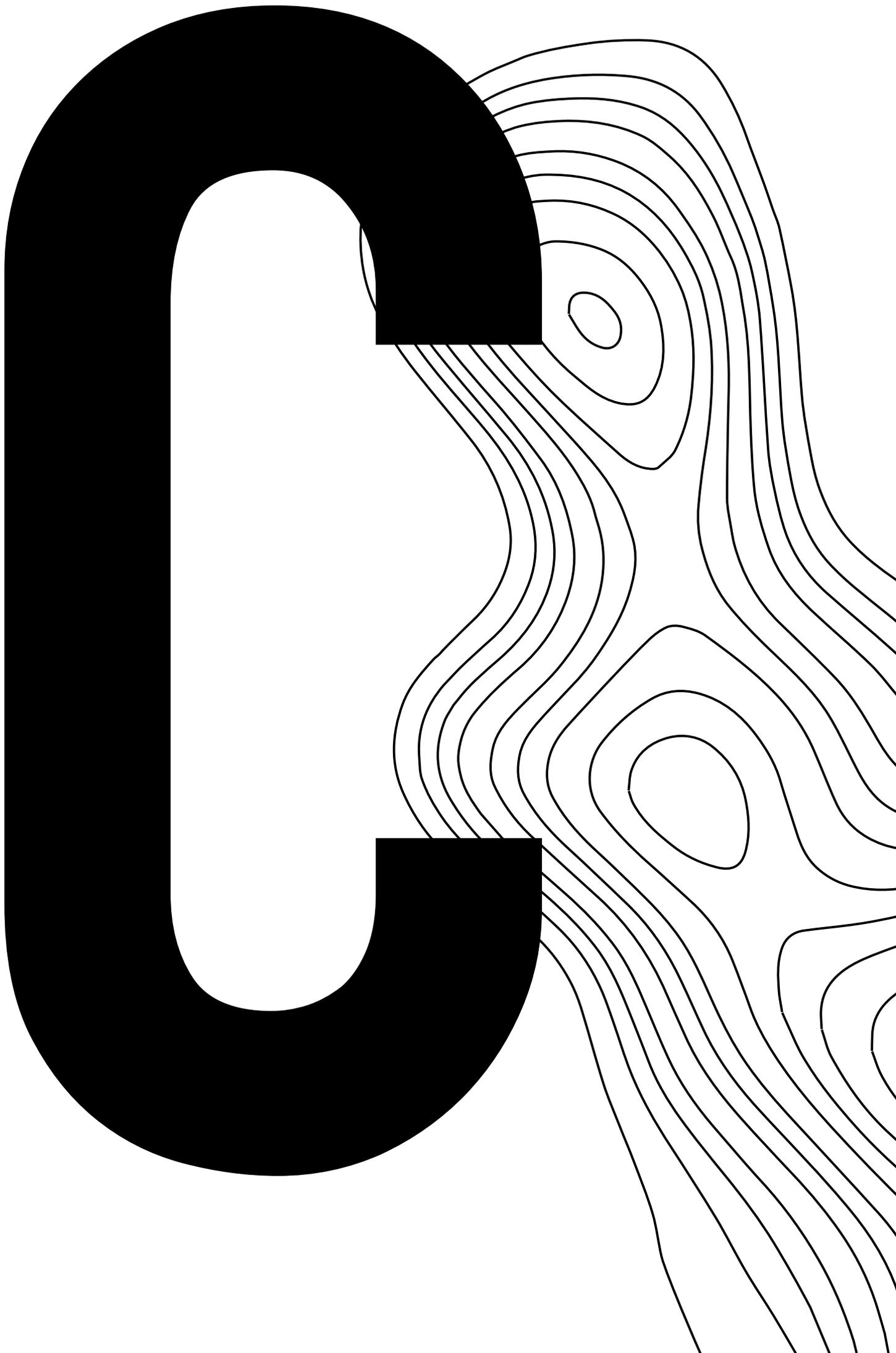
38. Some countries have standard sampling and analysis methods for other environmental media.<sup>8</sup> The International Standards Organization also has the following standards for soil and water quality sampling:

- (a) ISO 18400-104, Soil quality – Sampling – Part 104: Strategies;
- (b) ISO 18400-202, Soil quality – Sampling – Part 202: Preliminary investigations;
- (c) ISO 18400-204, Soil quality – Sampling – Part 204: Guidance on sampling of soil gas;
- (d) ISO 5667-11, Water quality – Sampling – Part 11: Guidance on sampling of groundwaters.

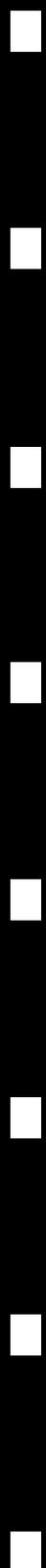
39. If human biomonitoring is undertaken, the World Health Organization survey protocol and standard operating procedures for human biomonitoring for the assessment of pre-natal exposure to mercury (WHO, 2018a and 2018b) are helpful.

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<sup>8</sup> See, for example, United States Environmental Protection Agency, Method 1669 “Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels”; Method 1630 “Methyl Mercury in Water by Distillation, Aqueous Ethylation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry”; Method 1631 “Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry”; and Method 7473 “Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation and Atomic Absorption Spectrophotometry”.



# ENGAGING THE PUBLIC



# C ENGAGING THE PUBLIC

40. When addressing contaminated sites, whenever possible, parties could consider strategies to promote public engagement, particularly on sensitive issues such as the presence of nearby contaminated sites, to ensure 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 required by legislation in certain jurisdictions. The focus of public engagement is to ensure that people (or groups) who could be affected by, involved in or interested in an action are informed and that their views are considered in the decision-making process. It is therefore important to consider engaging the public early in the process of identification or detailed assessment of a contaminated site. Parties are encouraged to consider developing a communication strategy to convey relevant information. Local knowledge can be very important for identifying potentially contaminated sites and deciding on a sampling strategy.

41. Different methodologies for engaging the public may be appropriate, depending on the phase of the process (site identification, investigation, remediation, aftercare, etc.). Parties are encouraged to consider disseminating the results of the public consultation process and decisions on future activities in a similar manner as the initial information at the start of the engagement process.

42. Effective communication, along with a two-way process of transmitting and receiving information, is important for increasing understanding among stakeholders. Scientific information, if available, should be disseminated through the most effective means for the community involved to narrow the gap between real and perceived risk.

43. Community outreach targets 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.

44. 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. For example, excavation of contaminated materials and in-situ treatment can release dust, vapours and odours. If available, the expertise of community members may contribute to an understanding of what issues need to be evaluated. Community leaders may contribute significantly to ensuring the implementation of a planned activity given that they have more influence on local stakeholders. 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.

45. 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 be taken (for example, installing fencing to prevent entry to contaminated areas, covering contaminated soils), as well as with site remediation activities. Ongoing activity at the site might make such engagement more difficult. It may also be useful to include 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, could also be provided. The initial information could

be provided through the distribution of printed material (such as flyers) directly within the community, workshops, or through publication in local or community newspapers or on relevant websites. Local websites, radio and television stations can be used to disseminate information and publicize key activities.

46. It is advisable to draft an initial plan setting out the ways in which the public will be engaged, including a timeline for the proposed engagement activities. Where inputs are being solicited, information should be provided on how the input will be collected and how it will be used. Public engagement activities should include public meetings, which may be held at central community locations, or, in some cases, at the affected site. Public meetings could have different formats, and different types of meetings may prove useful at different stages of the work.



# HUMAN HEALTH AND ENVIRONMENTAL RISK ASSESSMENTS

# D HUMAN HEALTH AND ENVIRONMENTAL RISK ASSESSMENTS

47. Risk assessment will help to answer the following questions:
- Does the site represent a risk to the human population and/or to the biota?
  - What is the magnitude of the risk?
  - Can the site risk be adequately managed without site remediation (in the near term or over a longer period), or should the site be remediated to reduce the risk (in the near term or the long term)?
  - If the site is not remediated, could the risk increase and/or spread?
48. Risk assessment is a process that estimates the magnitude and probability of the adverse effects of contamination to human health and the environment. Consequently, it is an instrument that can help to define whether environmental measures might be effective at a contaminated site and if so, which type of measure.
49. Risk assessment can be used to help define remediation or management objectives for a site, such as (a) to reach the maximum acceptable limits established by national or local legislation or relevant authorities or (b) to reach specific risk-based limits set for the site on the basis of the assessment. In order to support justified risk-based decision-making and sustainable risk management,<sup>9</sup> a site-specific assessment that relies on a well-defined CSM (i.e., source-pathway-receptor linkage) and takes into account local site conditions and background values could be regarded as a primary tool for determining the need for risk management actions.
50. Risk assessment is generally carried out in four clearly defined stages with specific objectives in order to identify hazards, dose and risk relationships, and to measure the magnitude of exposure to determine the risk level and estimated impact on the exposed receptors:
- Identification and characterization of the scope* (e.g., extent of contamination, proximity to human populations, depth to groundwater, proximity to surface water or sensitive habitats): The risk assessment may target the effects on human health, terrestrial animals and aquatic biota of elemental mercury, inorganic mercury compounds and methylmercury, as well as other contaminants. Human health will often be the priority. The scope of a risk assessment is determined by sitespecific needs.
  - Analysis of the hazard level and toxicity*: The hazards of mercury and mercury compounds are well recognized, with extensive scientific information available on the effects of exposure to mercury (WHO, 2017). 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.
  - Analysis of exposure*: The goal is to estimate the rate of contact between the identified contaminants and humans or the environment. The analysis is based on a description of actual and possible exposure scenarios, as well as characterization of the nature and extent of the contamination. This may involve exposure measurements such as testing of water supplies, locally grown food, seafood, and human scalp hair and urine. Measurements of mercury levels in sediments and fish and other biota can identify potential ecologic effects.
  - Analysis of risks*: The results of the previous stages are combined to objectively estimate the probability of adverse effects on the protected elements under the specific conditions of the site.
51. Contaminated sites may result in locally increased levels of mercury, which may pose risks to both humans and the environment. Drinking contaminated groundwater or surface water can result in long-term exposure, 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 can form subsurface vapour (also termed soil vapour) that subsequently migrates into overlying buildings, becoming a significant source of indoor air inhalation exposure that should be considered (Agency for Toxic Substances and Disease Registry, 1999). Contaminated sites may result in leaching or surface runoff of mercury, which can contaminate groundwater or surface water, resulting in potential exposure to

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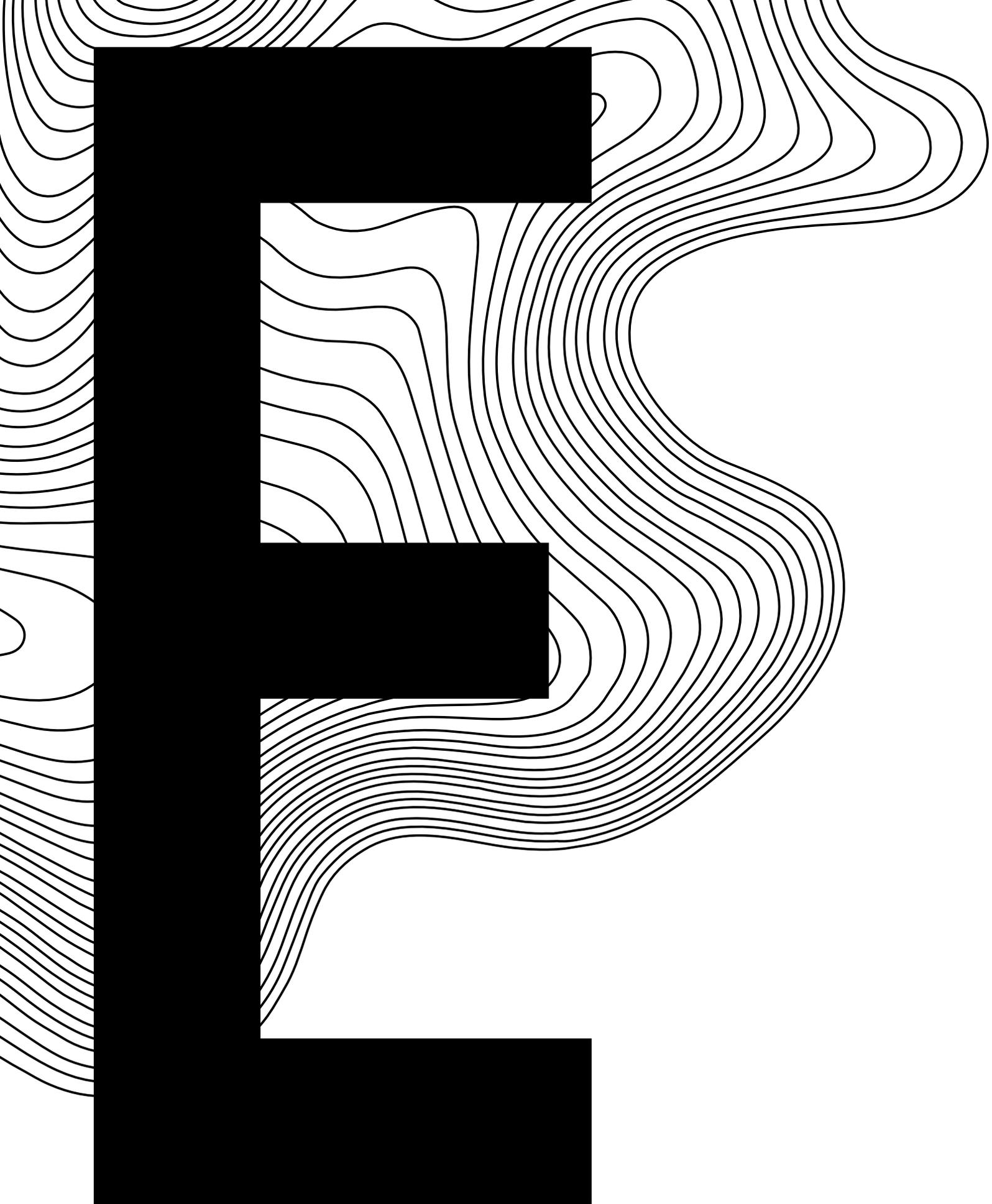
<sup>9</sup> Sustainable risk management means the elimination and/or control of unacceptable risks in a safe and timely manner, while optimizing the environmental, social and economic value of the work (ISO 18504:2017).

inorganic mercury through drinking water. A site's potential to contaminate groundwater, surface water or sediments 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 particular concern in relation to fish consumption. Several jurisdictions have established fish monitoring programmes and issued fish consumption advisories,<sup>10</sup> especially around known, suspected or historical point sources of mercury emissions.

52. The risks associated with a particular site are related to both the level of contamination and exposure due to current use. 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 areas of active methylation (wetlands, anaerobic soils, sediments and water) or with significant seepage into groundwater. Thus, site-specific clean-up targets can 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 the proximity of the local population. This information may have been gathered during the process of site identification and characterization 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.

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<sup>10</sup> See, for example, United States (<https://www.fda.gov/food/metals/mercury-concentrations-fish-fda-monitoring-program-1990-2010> and <https://www.fda.gov/food/consumers/advice-about-eating-fish>), Canada (<http://ec.gc.ca/mercure-mercury/default.asp?lang=En&n=DCBE5083-97AD-4C62-8862>) and the French Guyana health agency (<http://gps.gf/doc/catalogue/301/mercure-dans-les-poissons-et-grossesse-fleuves-de-guyane/>).



# OPTIONS FOR MANAGING THE RISKS POSED BY CONTAMINATED SITES

# E OPTIONS FOR MANAGING THE RISKS POSED BY CONTAMINATED SITES

53. Following assessment of a contaminated site, decisions are made 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 to protect 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 or local legislation and policies.

54. The main ways of technically addressing contamination resulting from previous industrial activities or other human activities are containment/isolation of the contaminants, immobilization of the contaminants, and clean-up or removal of the contaminants from the site, either in-situ or ex-situ. 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.

## 1. SITE MANAGEMENT

55. Site management includes actions taken to reduce exposure of humans and the environment to the mercury or mercury compounds present. Ongoing primary and secondary sources of contamination to groundwater or surface water may need to be considered.

56. In highly populated areas, land is a very precious and scarce resource. An unutilized contaminated or restored site may attract people for purposes of housing, farming or both. Parties may wish to restrict the use of the site and impose spatial planning rules in accordance with the risk present on the site. The decision on using such land requires thorough assessment and monitoring in order to ensure there is no residual risk to human health and the environment. Actions taken may include restricting site access to limit direct exposure (through fencing and warning signs) or defining restrictions on any activities that might mobilize the contamination at the site. If the water supply is contaminated, an alternative water supply or water treatment may be needed. 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 monitored to ensure that mercury is not migrating off site or developing the potential to affect the environment beyond the site boundaries. Soil sampling is likely to provide the best indication of the level of contamination; however, monitoring could also include measuring the soil gas and atmospheric levels of mercury around the site. If groundwater 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. 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.

## 2. SITE REMEDIATION

57. 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. When defining remediation objectives, the background mercury level should be considered. 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), availability of relevant technology, and the financial resources available for remediation. Remediation measures should also be undertaken with due consideration of the need to carry out such activities in a precautionary and sustainable manner.

58. There are a number of remediation approaches and technologies available, with a range of effectiveness and costs. 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, as well as factors such as permeability, organic matter and clay content, may also influence the choice of remediation method. A remediation strategy often requires a combination of several remediation techniques to address the issue properly. Evaluating and comparing individual remedial options to determine the most effective solution is crucial.<sup>11</sup>

### 3. SOIL TREATMENT

59. 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.

60. On-site containment of the mercury-contaminated area may be a viable option in certain circumstances. Physical barriers can be used to prevent mobilization of the mercury either through the soil or to air. 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.

61. 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, with appropriate care to prevent environmental pollution caused by the transportation of the soil. 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 its applicable environmental regulations. Moreover, soil exceeding the threshold for mercury contaminated waste should be managed in accordance with provisions for the environmentally sound management of mercury wastes pursuant to article 11 of the Convention. Offsite treatment of the excavated soil is aimed at either removing the contaminant or reducing the associated hazard to an acceptable level. If possible, the treated soil is sent back to the site or to another site. Soil treatment residues may contain high mercury concentrations and would need to be managed as mercury waste.

62. Excavation and other ground-disturbing activities at the site can, in some instances, be conducted within temporary air-tight structures using carbon filters and negative air pressurization. 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.

63. 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 size of 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.

64. 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 and

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<sup>11</sup> NICOLE (2015) presents several case studies and a summary of remediation approaches applied at mercury-affected sites. There are also websites that provide orientation for the selection of remediation techniques. See the Agence de l'Environnement et de la Maîtrise de l'Énergie and Bureau de recherches géologiques et minières, an interactive tool for preselection of remediation techniques (<http://www.selecdepol.fr/>) and Government of Canada, Guidance and Orientation for the Selection of Technologies (<http://gost.tpsgc-pwgsc.gc.ca/>).

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, sulfur polymer cement, sulfide, phosphate, cement kiln dust, polyester resins and polysiloxane compounds. These compounds vary in their effectiveness in binding mercury. Mixing of mercury with sulfur can stabilize the mercury as mercury sulfide, which reduces leachability and volatility; however, mercury sulfide can be converted back to elemental mercury under certain circumstances. A polymer stabilization process can be undertaken, where the mercury sulfide is microencapsulated in a polymeric sulfur 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.

65. 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.

66. Thermal treatment is used to treat industrial and medical wastes that contain mercury, but it is generally not suitable for soils with high clay or organic content. Mercury cannot be destroyed, and any form of thermal treatment should have the objective of separating the mercury from other matrices (such as soil and sediment) so that it can be managed as a hazardous waste in much smaller volumes in the form of concentrated mercury, and the matrix itself can be decontaminated. Treatment performance and costs are affected by the form of mercury present, particle size and moisture content, among other things. Thermal treatment is a process in which heat is used to volatilize the mercury, which can then be collected from the offgases. 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 and is not recommended for soils and sediment containing mercury, as the volume of contaminated vapours is significantly higher compared to indirect thermal desorption, due to the direct contact of heating fuel (gas, oil) combustion by-product gases. This results in much higher costs for catalysts and air pollution control mechanisms due to the increased volume of vapours that must be treated. Indirect thermal desorption involves heat applied to the exterior of a chamber that passes through the wall of the chamber to the material being treated. Indirect thermal desorption has the advantage of separating the offgases of the treated material from the combustion gases, significantly reducing the volume of contaminated gases to be filtered. The offgases from the treated material can be treated to recover mercury through, for example, condensation processes (Environment Agency, 2012). Hightemperature thermal treatment in retort ovens operating at temperatures of 425 to 540 degrees centigrade can be used for contaminated soils with a high concentration of mercury (US EPA, 2007). Incineration is not considered applicable to large volumes of mercury-contaminated material due to the high potential for mercury emissions and releases (Merly and Hube, 2014).

67. 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).

## 4. WATER TREATMENT TECHNOLOGIES

68. Contaminated sites could 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 options for addressing the issue, including containment and treatment. Treatment technologies include precipitation/coprecipitation, adsorption and membrane filtration (US EPA, 2007).

69. 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.

70. 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 spent 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.

71. 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.

## 5. GROUNDWATER TREATMENT TECHNOLOGIES

72. For groundwater, in-situ technologies can be considered. Important characteristics to take into account when selecting a remediation technology for groundwater are pH, the occurrence of other contaminants and parameters such as temperature and chloride content (Merly and Hube, 2014).

73. Proven remediation technologies for mercury-contaminated groundwater include pump-and-treat and permeable reactive walls (Merly and Hube, 2014).

74. Emerging remediation technologies for mercury-contaminated groundwater focus on increasing sorption media and filtration capacities for full-scale remediation of mercury-contaminated sites. Pump and stripping may also be considered if the efficiency of the treatment of heavily contaminated off-gas is improved. Research and development is currently being carried out on bioremediation, nanotechnology, the development of sorbent material (bio-sorbents, sorbents enabling adsorption of both organic and inorganic mercury) and the development of coagulation/flocculation processes (Merly and Hube, 2014).

## 6. SEDIMENT TREATMENT TECHNOLOGIES

75. If bottom sediments are contaminated with mercury, removal by excavation, capping or control of the release of methylmercury, such as by the addition of nitrate (Todorova and others, 2009; Matthews and others, 2013), may be appropriate. General guidance on remediation of sediment are proposed by the United States Environmental Protection Agency.<sup>12</sup> The potential for the release of mercury from sediment disturbance should be assessed and mitigation measures taken to ensure that any release is minimized and does not lead to unacceptable exposure for aquatic receptors.

76. In the event of excavation, technologies known to be effective for soil may be of use for sediments. The main barriers to effectiveness would be water and organic matter, and high salt content in the case of marine sediments.

## 7. OPTIONS FOR MANAGING RISKS SPECIFIC TO ASGM SITES WHERE MERCURY HAS BEEN USED

77. Sites contaminated by mercury resulting from ASGM activities are challenging to manage and remediate, as many can host occupied settlements, which limits the management and remediation options. Some newly established ASGM sites are only occupied for a short period due to a “gold rush” phenomenon and are abandoned once the ore body is depleted. Other sites may involve long-term occupation by groups who have worked an ore body for generations as an economic supplement to

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<sup>12</sup> General guidance on evaluating and remediating contaminated sediments, including those contaminated with mercury, can be found at <https://www.epa.gov/superfund/superfund-contaminated-sediments-guidance-and-technical-support>.

agricultural or other occupations. In some cases, the use of mercury for ASGM is divided between the mine site and nearby permanent settlements, where ball mills and other equipment extract more gold from concentrated ore. In such cases, mercury contamination can occur at both the mine site and the associated settlements, including residential settings some distance from the mine.

78. Identification of mercury-contaminated ASGM sites can follow the same preliminary site identification, detailed site identification and site characterization processes as any other mercury-contaminated site, but additional complexity arises when the site is active, occupied and in a dynamic state of contamination (i.e., new contamination is occurring constantly in new locations within the area in question). This differs from unoccupied sites, where the hotspots are relatively stable and the site can be characterized without the expectation of contamination arising at new locations within the overall site.

79. Mercury from historical small-scale gold production sites and currently operating ASGM sites can leach into water bodies such as rivers, lakes and impoundments, then recombine to form pools of elemental mercury on the river or lake bed, creating a source of long-term contamination. This form of mercury pooling can be detected using LiDAR scanning technology and removed using a vehicle-mounted vacuum suction unit fitted with carbon filters to prevent vapour releases. The holding tank allows environmentally sound removal of the mercury pools, which can be further treated in ex-situ vacuum distillation facilities and recovered for stabilization.

80. The complexity arising due to the overlap of ASGM activity, contamination and permanent or temporary settlement of the site makes public engagement and awareness-raising in the affected community essential. Section C of this guidance provides information on the establishment of a public engagement process for contaminated site remediation and management, but additional measures may need to be considered when engaging with communities conducting ASGM activities. ASGM sites can have a mix of transient and established workers. ASGM activities are also considered illegal in some locations, which can act as a barrier to effective engagement. The profile of the community at risk should be carefully considered before any attempt is made to develop an engagement programme, and potential representatives of informal miners, local settlements and health-care workers should be identified to assist with the development of the engagement process. All of these activities should occur within the context of, and be consistent with, the party's national action plan under article 7 of the Minamata Convention.

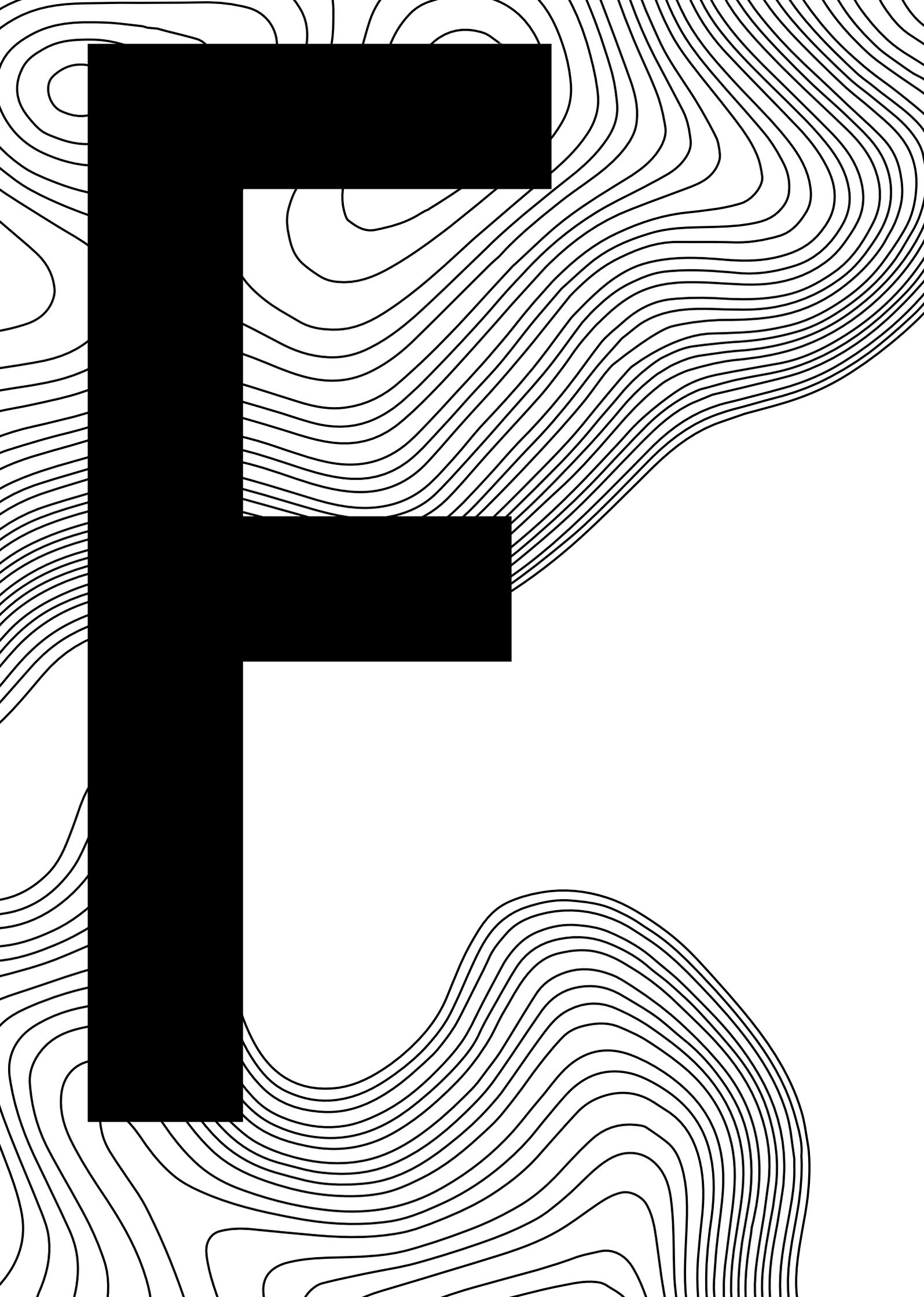
81. As the ASGM activity may be the sole economic activity in some locations, a local action plan may need to be developed with local representatives to inform and support miners in transitioning rapidly away from mercury use, identify and isolate contaminated hotspots, implement health surveillance and intervention measures and manage or remediate sites. Reducing or eliminating the use of mercury in ASGM is the preferred approach, as preventing contamination is invariably cheaper than remediation. Using this holistic approach with community support, the problems associated with dynamic mercury contamination can be reduced or even eliminated, allowing the site contamination to be managed effectively. A local action plan supported by government officials in cooperation with the affected communities can also include scenarios for alternate livelihoods for miners, reducing community opposition to the elimination of mercury use and the potential for ongoing contamination.

82. Technical measures for managing and remediating contaminated ASGM sites could take into account the fact that the sites may be located in remote areas that are difficult to access. If the objective of the management plan is to treat the contaminated media to remove mercury, then either equipment will need to be moved to the affected location or the soils and sediments will need to be transported to established treatment facilities. The latter scenario will, in most cases, prove prohibitively expensive. Standard methods and techniques for decontamination of soil, sediments and sludge based around ex-situ technology (generally on industrial sites) may therefore need to be adapted to permit smaller, modular, transportable and environmentally sound technologies to be brought to the contaminated site to treat the contaminated materials. In the case of contaminated water, this may be unavoidable.

83. In cases where it is possible to detect pooled mercury from ASGM activity on the beds of rivers, lakes or reservoirs using a remote sensing system such as LiDAR, technology has been developed to remove such pools without the significant sediment disturbance that can occur when dredging technology is applied.

84. Precautions must be taken when redeveloping former contaminated areas, as some rehabilitation measures can increase mercury mobility (Laperche and Touzé, 2014).

**THE**



# EVALUATION OF BENEFITS AND COSTS

# F EVALUATION OF BENEFITS AND COSTS

85. The likely costs and anticipated benefits of identifying, assessing, managing and/or remediating contaminated sites can vary widely. Each site will involve direct and indirect costs and benefits, as well as non-monetized costs and benefits. These factors, along with the availability of funding and the number of sites that may exist nationally, will be key inputs for national prioritysetting. Comparing very different sites may be difficult, but parties will inevitably need to decide which sites to pursue first.

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

87. Management or remediation of contaminated sites will entail costs, some of which will be oneoff 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 and cost of suitable technology nationally and local costs for consumables and labour.

88. Many of the available technologies have both initial capital costs and ongoing operation maintenance and monitoring costs. Some countries publish the cost associated with remediation techniques, but this can only be indicative, as some cost are country-dependant (US EPA, 2007; ADEME and BRGM, 2013). Parties can establish national priorities to ensure that the available funds are used effectively. Prioritization could be built on site ranking that uses a nationally agreed scoring system to identify the highest priorities. Such a system would need to find a balance between the estimated costs of management or remediation and the monetized and non-monetized benefits expected to result from effective site management. Extensive information is available on the applicability and possible effectiveness of some of the available technologies, while more limited information is available for other, less mature technologies.

89. The impact of site-related mercury exposure on the local population and the local environment may also entail costs, some direct (such as medical monitoring or care for people with adverse health effects) and others indirect (such as loss of income associated with contaminated fish that cannot be caught or sold, or lost cropland). Site management or remediation is intended to mitigate such costs in the future. 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 should be viewed from a very long-term perspective. Shortterm costs can include the impacts 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 of 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. New methods have been developed to estimate the economic costs associated with lost productivity due to the cognitive and development impacts of mercury on specific populations (Trasande and others, 2016), and these can be factored into long-term cost-benefit analysis of site management and remediation.

90. 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 these impacts entail costs that should be considered in any assessment.

91. Assessment of the benefits of site management or remediation should consider cultural and social values as much as possible. In many indigenous cultures, natural features such as rivers, lakes and landforms (and the animals that inhabit them) have high levels of cultural, religious and social value that do not feature in economic cost-benefit exercises. Yet the inability to conduct cultural activities due to contamination can have a very high cost for communities, resulting in deterioration of social cohesion and serious health impacts. National prioritysetting should incorporate social and cultural perspectives whenever possible.

92. Cost-benefit calculations should also take into account the ecological value of remediating contaminated ecological systems and their productivity as well as the economic value. For example, a remediated contaminated site may have characteristics that support rare and endangered species or act as a headwater catchment for major waterways.

### **Financing options for investigation and management of contaminated sites**

93. Jurisdictions around the world use many different combinations of finance options to meet the costs of site investigation and management. Some countries have dedicated technicians within government agencies to conduct such investigations, while others choose to engage specialist consultants or to use a combination of agency staff and consultants working together. Finding the resources to finance such work can be challenging but a number of options exist involving both the private and public sector.

94. Financing of contaminated site management and remediation should reflect the polluter pays principle whenever possible. This may require a legal and regulatory framework that places the onus of expenditure for site assessment, management, remediation, waste treatment and disposal on those responsible for the pollution. In the absence of an established legal framework, parties would need to take a case-by-case approach. In some cases, different levels of government may be responsible for the financing framework for contaminated sites.

95. Many national polluter-pays models for contaminated sites include provisions similar to the “orphan site” provisions of the European Union model. Orphan sites are sites for which the polluters no longer exist, cannot be identified or have insufficient funds to cover the costs of assessment and remediation. In some jurisdictions, the legal or administrative framework for determining responsibility for the cost of site management and remediation also have “innocent landowner” provisions that exempt a landowner who did not cause or have knowledge of contamination from contributing to the clean-up costs. The “Superfund” system<sup>13</sup> in the United States and the Western Australian legal framework<sup>14</sup> include this concept. In some jurisdictions, a landowner or other occupier of the property can be held liable for assessment and remediation costs associated with contamination caused by someone else. The contaminated sites register could be shared with the office or ministry responsible for land transactions, where appropriate, to facilitate the implementation of the polluter pays principle.

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<sup>13</sup> <https://www.epa.gov/enforcement/landowner-liability-protections>.

<sup>14</sup> Government of Western Australia (2003). Contaminated Sites Act 2003 Section 27 (2) (a).



# VALIDATION OF OUTCOMES

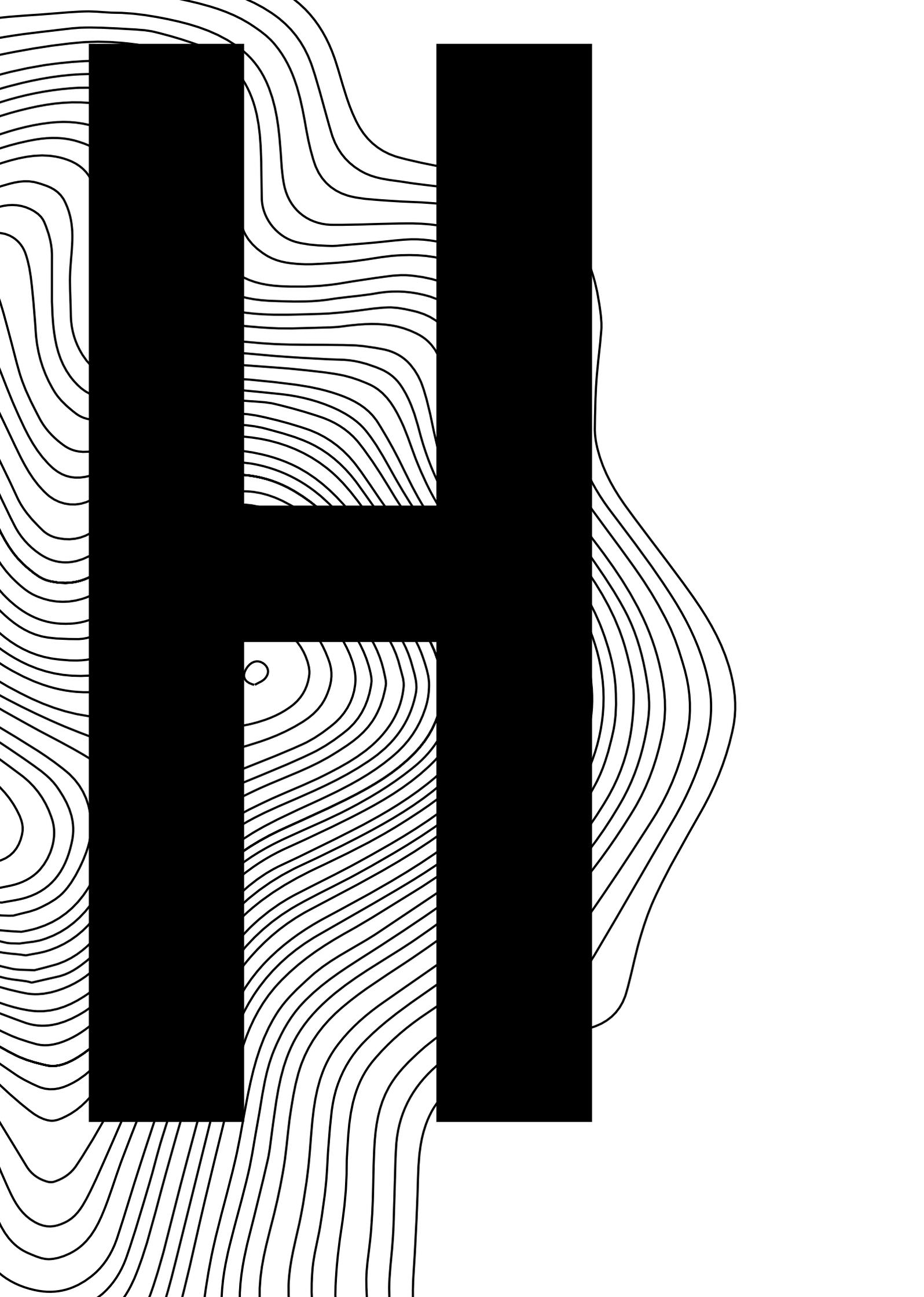
## G VALIDATION OF OUTCOMES

96. It is important to be able to verify whether the management or remediation actions taken have been effective in meeting the risk management or remediation goals established for the site. The means of verification should be established during the initial planning process, and the resources needed to undertake any necessary activities such as monitoring should be included in the overall project. Field measurement techniques could be used for this purpose in order to reduce costs associated with mercury determination (e.g., using portable x-ray fluorescent devices).

97. 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 in some instances need to be followed in an iterative fashion.

98. 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 at or below the remediation objectives in terms of mercury soil concentrations. Surface water and groundwater concentrations, atmospheric concentrations and levels in biota can also be measured to assess whether management and/or remediation objectives have been met.

99. 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. The monitoring programme should include appropriate ongoing monitoring of mercury levels in all the media of concern, even after remediation activities are complete, to ensure that remediation was successful and that there are no additional sources of contamination that were not identified during site characterization.



**COOPERATION IN  
DEVELOPING STRATEGIES  
AND IMPLEMENTING  
ACTIVITIES FOR  
IDENTIFYING, ASSESSING,  
PRIORITIZING, MANAGING  
AND, AS APPROPRIATE,  
REMEDIATING  
CONTAMINATED SITES**

# H COOPERATION IN DEVELOPING STRATEGIES AND IMPLEMENTING ACTIVITIES FOR IDENTIFYING, ASSESSING, PRIORITIZING, MANAGING AND, AS APPROPRIATE, REMEDIATING CONTAMINATED SITES

100. Cooperation between and among parties is encouraged in the Convention text, both specifically in article 12 on contaminated sites and within the provisions of article 14 on capacitybuilding, technical assistance and technology transfer. Cooperation could consist of, for instance, information-sharing activities, exploration of opportunities for joint assessment of sites or coordination of communication plans in relation to sites.

101. 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 ASGM, primary mercury mining or chlor-alkali production).

102. 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.

103. 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 multiple contaminated sites in close proximity. Parties may need to cooperate to restrict access to certain sites. In cases where remediation activities are planned, it might be possible to develop joint plans for the treatment of contaminated material, which could provide benefits of scale or allow treatment to be undertaken at specialized facilities.

104. There are a number of long-established regulatory networks relating to 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.<sup>15</sup> 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/>.

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