

Guidance on the management of contaminated sites

Contents

A.	Introduction.....	2
	Risks to human health and the environment.....	2
	Global use of mercury.....	3
	Mercury emissions and releases.....	4
	Obligations under the Minamata Convention on Mercury.....	4
B.	Site identification and characterization.....	4
	Site identification.....	4
C.	Engaging the public.....	8
D.	Human health and environmental risk assessments.....	9
E.	Options for managing the risks posed by contaminated sites.....	10
	Site management and remediation.....	10
	Soil treatment.....	11
	Water treatment technologies.....	13
F.	Evaluation of benefits and costs.....	13
G.	Validation of outcomes.....	15
H.	Cooperation in developing strategies and implementing activities for identifying, assessing, prioritizing, managing and, as appropriate, remediating contaminated sites.....	16
	References.....	17
	Appendix I	
	Framework and initial decision tree for management of contaminated sites.....	19
	Appendix II: Further technical information.....	20

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. It is intended to provide general advice to parties in non-prescriptive language, taking into consideration the variety of national circumstances of parties. It also distinguishes between contaminated sites and mining sites that are being managed in an environmentally sound manner. 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.

3. The term "contaminated sites" is not specifically defined in the Convention text. Countries may have their own definition in their legislation. The following definition of a contaminated site in the guidelines under the Mediterranean Action Plan (MAPUNEP, 2015) may be helpful: "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". 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, artisanal and small-scale gold mining (ASGM) sites (IPEN, 2016).

Risks to human health and the environment

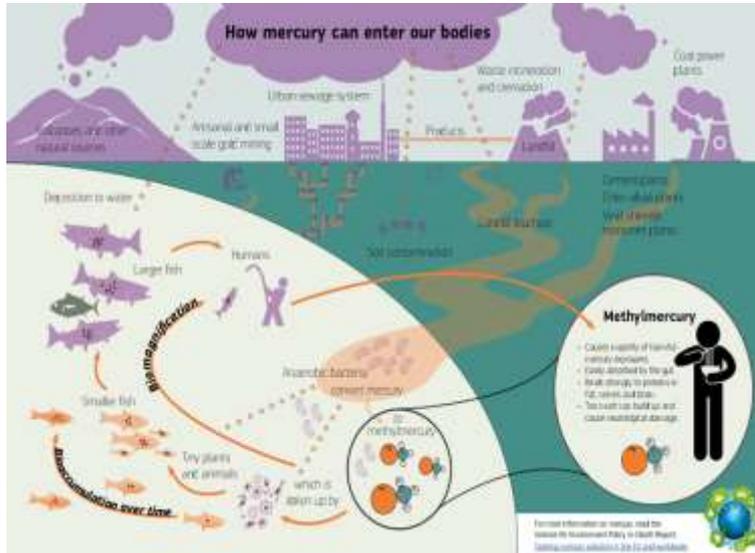
4. Mercury is a naturally occurring chemical element that is found in air, water and soil. It is emitted and released into the environment from volcanic activity, weathering of rocks and as a result of human activity. Main anthropogenic sources of mercury emissions and releases include ASGM, coal burning, industrial processes, waste incineration and mining.

5. 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 deposited to deep ocean sediments or mineral soils. Mercury exists in various forms: elemental (metallic), inorganic and organic. 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.

6. 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.

7. 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 ASGM) 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.

Commented [L1]: Risk assessments has nine exposure pathways for agricultural and non-agricultural landuses. The pathways included consumers ingesting plants grown in waste-amended soils (pathway one), children ingesting waste materials directly (pathway two), farms producing animal products that consumed eat plants grown in waste-amended soils (pathway three), human consumption of livestock that ingest soil directly from waste material directly while grazing (pathway four), livestock ingesting crops grown on waste-amended soils (pathway five), grazing livestock ingesting waste-amended soils (pathway six), plant grown in waste-amended soils (pathway seven), soil biota living in waste-amended soil (pathway eight), and human consuming groundwater that are directly located under waste disposal site (pathway nine).



Global use of mercury

8. 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 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 activities such as ASGM and dentistry.
9. 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 offsite, 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).
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 mercury releases to waste water 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, 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 and in the surroundings.

Commented [L2]: Pesticides is use of mercury that was not be mentioned. This is the most important in food safety and human health.

13. Mercury can also be emitted by a number of 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

14. The 2018 Global Mercury Assessment indicated that the largest sources of anthropogenic emissions of mercury to air are ASGM and coal combustion (UNEP, 2019), followed by the production of ferrous and non-ferrous metals and cement production. The 2018 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 2015 were estimated at 2,220 metric tons, while anthropogenic releases to water and soil were at least 1,800 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. [Data will be updated after the publication of the technical background document for Global Mercury Assessment 2018.] Other studies (Kocman et al., 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

15. 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.

16. 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

17. 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 activities likely to result in mercury releases. As noted

Commented [L3]: Natural sources of mercury include volcanoes, forest fires and that should be mentioned

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, and other industrial operations. It also includes abandoned sites of gold and other non-ferrous metals mining 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 countries to begin prioritizing their response to their contaminated sites in line with existing legal frameworks, where applicable.

18. A systematic approach may be taken for the identification of contaminated site. It 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. This approach can be supplemented by identification of individual contaminated sites, such as when changing the character of the land. Individual identification of contaminated sites can be effective and efficient when a country has performed some degree of contaminated site identification and applied environmentally appropriate management measures.

19. 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.

20. 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 emissions and releases
- waste management.

Sources such as the manufacturing of mercury-added products, the 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 while there will be a primary contaminated site, there may also be associated secondary sites with contamination because of runoff, 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.

21. 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. Information collected for the development of a national action plan pursuant to article 7 may be useful in the identification of contaminated sites.

22. 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 investigations. In some jurisdictions, government agencies, businesses and private landowners are required by law¹ to notify the competent environmental authorities if they hold land that is suspected or known to be contaminated, failing which they face financial penalties.

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

- Records identifying past industrial or other activities at the site

¹See, 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>.

Commented [L4]: The oil industry is also one of the potential sources of mercury contamination. It is also necessary to highlight this activity to attract the attention of oil-rich countries such as ASGM.

- 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
- Existing physical or analytical results showing contaminant levels
- Community reports to the authorities regarding suspected releases

Inventory development

24. As identification of suspected and confirmed contaminated sites within a jurisdiction progresses, it becomes possible to develop a database or inventory of multiple sites which can be used to track assessment and management of individual sites over time. Inventories would allow governments to use a risk based approach to efficiently prioritise the use of resources to protect human populations and parts of the environment at most immediate risk from exposure from the most hazardous sites. Those sites presenting the highest risk can be managed as a priority and those sites that present a low risk can be have resources allocated at a later point in time.
25. Inventories can act as a 'living database' in the sense that sites can be added as they are discovered (such as legacy sites that may be very old with no records uncovered during unrelated construction works) and sites may be removed as they are demonstrated not to be contaminated or have been fully remediated. However, rather than removing sites from a database that have been remediated, it may be prudent to classify them as remediated and leave them on the database in the event that advances in science require the site to be reassessed at a later date. This may be the case if acceptable soil levels for a specific contaminant are significantly revised downward rendering a site 'contaminated' due to the previous remediation no longer meeting the new criteria.
26. Inventories can have internal classification systems that assist with land use planning and development approvals for authorities and to track assessment and management of sites. One example used by an Australian state jurisdiction employs the following seven classifications;
- Contaminated – remediation required
 - Contaminated – restricted use
 - Remediated for restricted use
 - Possibly contaminated – investigation required
 - Decontaminated
 - Not contaminated -unrestricted use
 - Report not substantiated².
27. An innovative approach to inventory analysis is to combine inventory data with a GIS mapping system to provide an online database available to the public which shows the location of confirmed contaminated sites³.

Commented [PR5]: The risk level depends on the environmental conditions (in highly permeable soils, low levels of mercury can also cause groundwater contamination)

Site characterization

28. Once potentially 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.
29. The potentially contaminated sites identified can be further characterized through phased investigation. Countries may establish their priorities for site characterization, based on the type of land use history. Countries with significant ASGM activities or with decommissioned mercury-cell chlor-alkali plants may prioritize these sectors. Preliminary site investigation or initial site screening,

² This jurisdiction allows any member of the public to report a suspected contaminated site using a standardised form and then subjects the site to investigation.

³Contaminated Sites Database of Western Australia
<https://dow.maps.arcgis.com/apps/webappviewer/index.html?id=c2ecb74291ae4da2ac32c441819c6d47>

which may involve site visits and review of available information, can be a useful tool for prioritizing for detailed site investigation.⁴

30. The development of a conceptual site model for the site can be a useful step.⁵A conceptual site model is a visual representation and narrative description of the physical, chemical and biological processes that may occur, occurring, or that have occurred, at a site. Its specific elements may include the following (CCME, 2016):⁶

- An overview of historical, current, and planned future land uses;
- 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;
- 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, country foods, or biota) that may be affected;
- The distribution of chemicals within each medium including information on the concentration, mass and/or flux;
- 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;
- Information on climate and meteorological conditions that may influence contamination distribution and migration;
- 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; and,
- Information on human and ecological receptors and activity patterns at the site or at areas impacted by the site.

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

- Characterizing the types of contaminants present at the site
- Developing an understanding of the site geology and hydrogeology
- Delineating the extent and distribution (vertical and lateral) of contamination
- Characterizing the actual migration of contaminants
- Obtaining data to identify and assess the actual potential adverse effects to the public health and the environment.

32. 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)

⁴Some 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 methyl mercury (Environment Agency UK 2009). The Australian national guidelines for contaminated sites (NEPC 1999) listed 10 ppm methyl mercury and 15 ppm elemental mercury as a screening level for residential property.

⁵ISO 21365 (2018) Soil quality - Conceptual site models for potentially contaminated sites

⁶Health 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>.

- 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 plan

33. 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 and intervals; and the contaminants of interest (mercury, methylmercury and/or other mercury compounds). When determining the sampling plan, practical considerations are needed such as logistics, transport and preservation of samples, availability of equipment, and cost.

34. Some countries have standard sampling and analysis methods for other environmental media. There are following ISO standards on sampling for soil and water quality:

- ISO 18400-202, Soil quality — Sampling — Part 202: Preliminary investigations
- ISO 18400-104, Soil quality — Sampling — Part 104: Strategies
- ISO 18400-204, Soil quality — Sampling — Part 204: Guidance on sampling of soil gas
- ISO 5667-11, Water quality — Sampling — Part 11: Guidance on sampling of groundwaters

35. WHO published a survey protocol and standard operating procedures for human biomonitoring for the assessment of pre-natal exposure to mercury (WHO 2019a and 2019b).

[Some guidance on sample analysis may be helpful.]

C. Engaging the public

36. When addressing contaminated sites, Parties might 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 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 considered in the decision-making process according to their roles and responsibilities. It is therefore important to consider 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.

37. 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.

38. 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.

39. 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

Commented [L6]: The Soil Doctors programme of FAO is a viable example of capacity building and strengthening capacity development through training of specific experts who will be in charge of the dissemination of knowledge to other soil users. Potential implementation measures could include: initiatives such as the Global Soil Doctors Programme should be established in order to provide support and capacity development for extension on mercury waste management where formal extension services are not available;

mishandling of mercury waste or products, for example, the source issue should be addressed before any additional action is taken.

40. 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.

41. 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.

42. 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. 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.

43. It is recommended that an initial plan setting out the ways in which the public will be engaged is 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.

D. **Human health and environmental risk assessments**

44. Risk assessment will help to answer the following questions:

- Does the site represent a real or potential risk to the human population and/or to the biota?
- What is the magnitude of the risk?
- Should the site be restored to reduce the risk?
- If the site is not restored, could the risk increase and/or spread?

45. Risk assessment is a process that assigns magnitudes and probabilities to the adverse effects of contamination. Consequently, it is an instrument that can help to define whether or not environmental measures should be implemented at a contaminated site. Risk assessment can establish the urgency to act: the greater the risk of the contamination affecting living beings, the greater is the need to implement restoration programmes.

46. Risk assessment can be used to define remediation objectives for a site, which may be to reach (a) the maximum acceptable limits established by legislation or relevant authorities or (b) specific limits set for the site on the basis of the assessment.

47. Risk assessment can be carried out in four clearly defined stages with specific objectives:

Commented [L7]: In addition to all the points in this section, soil properties (pH, organic matter, clay% ...) are the most effective in the hazard level and toxicity of mercury. In Iran, risk assessment is based on the characteristics of the soil that proposal document is being prepared.

- Identification and characterization of what is at risk. Effects of elemental mercury, inorganic mercury compounds and methylmercury on human health, terrestrial animals and aquatic biota are to be addressed. Other contaminants may be addressed in the risk assessment.
- Analysis of the hazard level and toxicity. The hazards of mercury 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 aim is to estimate the rate of contact with the identified contaminants. The analysis is based on a description of exposure scenarios, as well as characterization of the nature and extent of the contamination. This may involve exposure measurements such as the scalp hair and urine.
- Analysis of risks. The results of the previous stages are combined to objectively estimate the likelihood of adverse effects on the protected elements under the specific conditions of the site.
- Other contaminants besides mercury may have an impact. Therefore, if there is evidence that other contaminants are present at the site, those who are responsible for the process must take the decision to include them in the study and assessment.

48. 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 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 (Agency for Toxic Substances and Disease Registry, 2001). 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 particular 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.

49. The risks associated with a particular site are related to both the level of contamination and the 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 may 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 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.

E. Options for managing the risks posed by contaminated sites

Site management and remediation

50. 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.

51. 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.

52. 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.

53. 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 monitored and reviewed to ensure that mercury is not migrating offsite 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.

54. 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 soil gas and 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.

55. 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.

56. There are a number of remediation approaches and technologies 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 as well as consideration link to the subsoil (composition, permeability, organic matter content, etc.). It should be noted that 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 a crucial aspect.

Soil treatment

57. 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.

58. 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.

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

Commented [L8]: Soil contamination threshold is necessary for soil treatment. In Iran this standard depend on land use and soil properties is brought at the end of this document.

and would need to be managed as mercury waste. Note, too, that when contaminated soil is treated and disposed of offsite, the conditions of the waste management unit can have an impact on treatment effectiveness.

60. 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.

61. 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.

Commented [L9]: using bioremediation and phytoremediation methods in agriculture soil can treat soil with maintaining food safety.

Commented [L10]: And soil properties (pH, organic matter, clay% ...)

62. 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 offsite. 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.

63. 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.

64. 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. Mercury cannot be destroyed and any form of thermal treatment should have the objective of separating mercury from other matrices (such as soil and sediment) so that it can be managed as hazardous waste in much smaller volumes as concentrated mercury while decontaminating the soils treated. 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 and is not recommended for soils and sediment containing mercury as the contaminated vapours are significantly increased compared to indirect thermal desorption, due to the direct contact of heating fuel (gas, oil) combustion by-product gases. This results in much higher expenses for catalysts and air pollution control mechanisms due to the increased volume of flue gas that must 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.⁷ However, 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)

65. 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 et al, 2015).

Water treatment technologies

66. 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. However, an assessment of the potential release of mercury from sediment disturbance should be conducted and mitigation measures taken, to ensure that any release is minimised and does not lead to unacceptable exposure for aquatic receptors.

67. 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.

68. 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.

69. 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.

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.

Commented [L11]: soil is a complex porous environment and pollutants go into the processes of adsorption, precipitation, dissolution, absorption by plants, decomposition, and transport. Thus, in order to impose fines for soil pollution the effect of soil properties on the fate of contamination should be considered. The remediation method used in soil cleanup is also affected by the soil properties. A model has been proposed to determine remediation cost of polluted soils in Iran. In the model the most important factors that affect the fate of soil contamination are used to calculate cost of soil cleanup. The factors used in the model are: soil pH, amount of clay, percent organic matter content, depth of water table, distance from sensitive area (cities, surface water bodies, parks, agricultural areas, ...), contaminant concentration in the soil and the method used for soil remediation (soil cleanup). **(Iran proposal is being prepared)**

⁷http://www.mercuryconvention.org/Portals/11/documents/forms%20and%20guidance/English/BATBEP_introduction.pdf.

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 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 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. 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 et al 2016) and these can be factored into long term cost benefit analysis of site management and remediation.

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 offsite or atmospheric contamination from mercury vapours. All of these impacts entail costs that should be considered in any assessment.

76. Cost-benefit calculations should not consider only economic calculations that discount cultural and social values. 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 are not a feature of economic cost-benefit exercises. Purely economic calculations render such value invisible and decision may be made not to remediate a site based on economic cost alone. Yet the cost implications for mental health impacts on communities of not being able to conduct cultural activities due to contamination may be very high and result in deterioration of social cohesion and health related impacts. Cost-benefit decisions should always involve social and cultural perspectives.

77. Cost-benefit calculations should also place value on remediation of contaminated ecological systems and their productivity in ecological and not just economic terms. For example, a remediated contaminated site may have characteristics that support rare and endangered species or act as a headwater catchment for major waterways. Such sites should not simply be assigned an economic value for agricultural production within its boundaries but the remediation of a such a site should consider the broader ecological benefits that result.

Financing options for contaminated site investigation and management

78. There are many different combinations of finance options implemented in different jurisdictions around the world to meet the costs of site investigation and management. Some countries may have dedicated technicians within government agencies to conduct such investigations while others choose to engage specialist consultants to undertake such work. In other circumstances a combination of agency staff and consultants work together to address contaminated sites. Providing resources to finance their work can be challenging but a number of approaches exist that can involve the private and public sector.

79. Financing contaminated site management and remediation should take the polluter pays approach. For this to be effective, a legal and regulatory framework need to be established that places the onus of expenditure for site assessment, management, remediation, waste treatment and disposal on those parties responsible for the pollution.

80. In the US, the polluter pays approach is utilised and a pool of funds has been established for this purpose known as the 'Superfund'⁸ which is authorised by a legal framework known as

⁸For further information see <https://www.epa.gov/sites/production/files/documents/thesuperfundcleanupprogram.pdf>

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The money that constitutes the 'Superfund' is based mainly on taxes levied against petroleum and chemical industries in an acknowledgement that generate the majority of contaminated sites in the US.

81. In New Zealand 'The Contaminated Sites Remediation Fund' is administered by the national government and provides up to a total of 2.6 million NZD each year to local governments to address the ten highest risk sites that are nominated to the fund via an application process⁹.

82. In the UK liability for the costs of land contamination investigation and management are determined according to the "polluter pays principle" defined legally in sections 78J and 78K of the Environmental Protection Act 1990 and statutory guidance (Environment Agency UK 2016).

83. In South Africa liability for contaminated sites costs is also attributed to the polluter under Section 28 of the NEMA (National Environmental Management Act).

84. EU member states apply the "polluter pays principle" to the maximum extent, while there are exceptions such as where the polluter cannot be identified or cannot afford to cover the costs of investigation and management/remediation. Within the EU, public funds account for up to 35% of total expenditure on contaminated sites where the responsible polluter cannot be identified or cannot pay for the site works. In some member states such as Czech Republic, Macedonia and Spain public funds account for 100% of clean up costs (Ministry of Environment, Slovak Republic 2010).

85. Many national polluter pays models for contaminated sites include similar provisions to the EU model where 'orphan site' provisions apply. The concept of 'orphan sites' is one where polluters of the site cannot be identified, have insufficient funds to cover the costs of assessment and remediation or the site is historical and no responsible entity still exists. Consideration should also be given to 'innocent landowner' provisions where the current occupant of the impacted land purchased it without knowledge of the contamination that has been caused in the past. In some jurisdictions, the occupier of the property may be liable for financing assessment and remediation cost yet may not have caused the pollution and this should be taken into account.

86. Most jurisdictions that have not developed finance mechanisms for contaminated sites assessment and management may consider a formal legal framework for polluter pays liability but be prepared to create a public fund to address high risk sites where no polluter can be legally held accountable. In some cases, different levels of government may be responsible for creating contaminated sites through state owned enterprises and/or public landfill facilities and a public fund will be necessary to address these sites.

G. Validation of outcomes

87. It is important to be able to verify whether management 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.

88. 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.

89. 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.

90. 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.

Commented [L12]: like as iran (Soil Protection Act-article 15)

Commented [L13]: The monitoring system under web-GIS will be helpful to the validation of outcomes.

⁹ <http://www.mfe.govt.nz/more/funding/contaminated-sites-remediation-fund/about-fund>

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

91. 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.

92. 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.

93. 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).

94. 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.

95. 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.

96. 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.¹⁰ 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/>.

¹⁰CLARINET – 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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[To be double-checked after the finalization of the text]]

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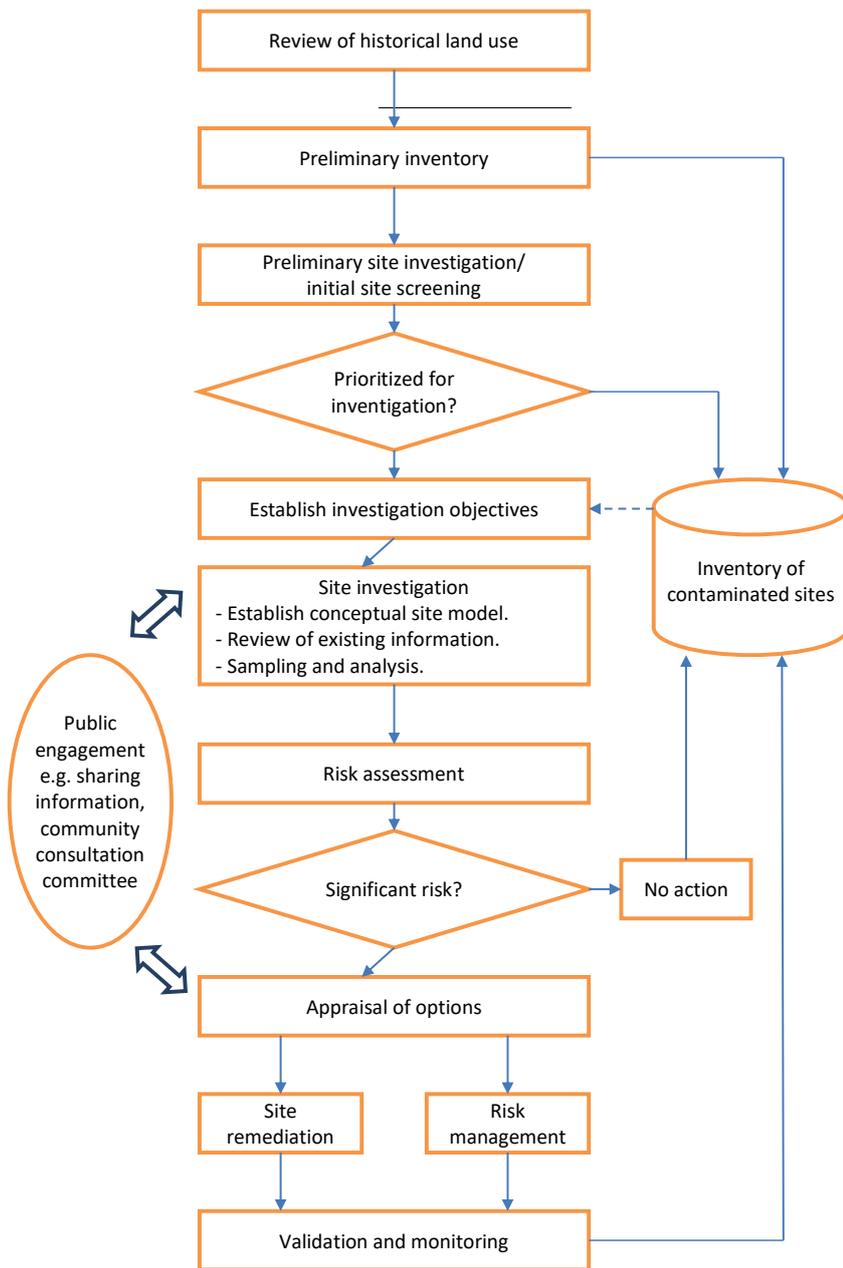
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Appendix I

Framework and initial decision tree for management of contaminated sites



Appendix II

Further technical information

In the process of developing this guidance, parties and other stakeholders submitted information on national policy, legislation, case studies etc. that may be helpful in decision making on the management of contaminated sites, as compiled in this appendix.

Situations that are site-specific to mercury that parties may face

<Canada>

Hydrometric monitoring stations using servo-manometers: Prior to 1997, Quebec hydrometric monitoring stations were operated using mercury servo-manometers. Due to large fluctuations in water levels, mercury was, in some cases, released from the instrument and ended up in the nearby sediments. Since 1997, all hydrometric sites in southern Quebec have been decontaminated.¹¹

Chlor-alkali facilities: Due to the absence of environmental regulations prior to the 1970s, the lands of former industrial plants in Quebec could be contaminated with mercury. At one chlor-alkali production facility, 360,000 cubic metres of mercury-contaminated soil was treated using a physical separation process to recover liquid mercury and placed in a specially constructed containment cell located on the same property. As sediments of the river downstream of the facility were also found to be contaminated with mercury, they were dredged and added to the containment cell.¹²

Harbours and lighthouses: The surrounding soils and sediments around lighthouses and harbours may be contaminated with mercury due to the use of mercury containing products (e.g. paint, fungicide, lightbulbs, batteries) used in the construction, operation, and use of these structures. In many cases, the soils and dredged sediments are placed in specialized containment cells on or offsite.

A description of the successful remediation of certain federal contaminated sites in Canada can be found on this website: <https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites/success-stories.html>. While these sites are not all mercury-contaminated sites, they may be helpful case studies to draw upon when preparing the draft guidance document.

<Switzerland>

A major chlor-alkali plant of the CABB Company is situated in Pratteln in the canton of Basel-Landschaft. It is the only one in Switzerland that is still in use. Since about 2015, however, mercury has no longer been used for the chlor-alkali process.

At Lonza site in the canton of Valais, mercury was mainly used in the production of acetaldehyde from acetylene.¹³

<Other information>

Sino-German Workshop 2008 REMCOSITE - Remediation of mercury contaminated sites, Guiyang, May 27 – 30, 2008. <https://www.grs.de/en/node/1180>

Laperche V., R. Maury-Brachet, F. Blanchard, Y. Dominique, G. Durrieu, J.-C. Massabuan, H. Bouillard, B. Joseph, P. Laporte, N. Mesmer-Dudons, V. Duflo et L. Callier (2007). Répartition régionale du mercure dans les sédiments et les poissons de six fleuves de Guyane. Rapport BRGM/RP-55965-FR. <http://infoterre.brgm.fr/rapports/RP-55965-FR.pdf>

Laperche V. Touzé S. (2014) – Restauration de l'état des masses d'eau de surface contaminée par le mercure - Etat de l'art des méthodes existantes et adaptabilité dans le contexte guyanais. Rapport final. BRGM/RP-64032-FR.

The role of inventories of contaminated sites in strategies and policies relating to contaminated sites

¹¹For more information see Service des lieux contaminés – MDDEP, 2006. Programme de réhabilitation des stations hydrométriques contaminées au mercure (Période 2003-2005).

¹²For more information see Dessau, Soprin (2004). Projet conjoint PPG Canada inc. et Alcan inc. Restauration d'un tronçon de la rivière Saint-Lois, Beauharnois, Québec. Étude d'impact sur l'environnement déposée au ministre de l'Environnement.

¹³<http://quecksilber.lonza.com/quecksilber/wofuer-hat-lonza-quecksilber-genutzt>

Commented [PR14]: Iran:

- 1-The chlor-alkali units of the petrochemicals were shut down and new technologies were replaced.
- 2-Soil reclamation sites were designed and implemented
- 3-Soil protection Act was approved.
- 4-Preparation of Iranian Soil contamination threshold and its guidelines based on soil characterization and land use are following:
 - ✓Risk Assessment of Environmental Status and Quality of Soils
 - ✓Guidelines for estimating costs and fines resulting from soil pollution
- 5-Setting up the site for Soil contamination threshold and its guidelines at the following address:
<http://v3.soilstandards.ir/Index.aspx>
- 6-Construction of soil pollution Atlas has been started in 13 provinces among 30, (diagram in attach 1)
 - In this projects, the major hotspots (contaminated lands) and also the main sources of contamination would be identified and prioritized for remediation act.
 - Also, based on these projects a master plan would be defined to control, reduce, and prevent the pollution and to implement the structural or non-structural means of pollution control.

<Canada>

Between 2000 and 2002, the Treasury Board of Canada approved a policy framework for the management of federal contaminated sites. The framework was a collection of policies and best practices to guide federal organizations (custodians) in the management of federal contaminated sites and was accompanied by the public release of the FCSI.

The FCSI includes information on all known federal contaminated sites under the custodianship of departments, agencies and consolidated Crown corporations as well as those that are being or have been investigated to determine whether they have contamination arising from past use that could pose a risk to human health or the environment. The inventory also includes non-federal contaminated sites for which the Government of Canada has accepted some or all financial responsibility. It does not include sites where contamination has been caused by, and which are under the control of, enterprise Crown corporations, private individuals, firms or other levels of government.

To date, departments, agencies and consolidated Crown corporations have identified and classified over 22,000 contaminated or suspected contaminated sites in urban, rural and remote areas across Canada, using the CCME's National Classification System for Contaminated Sites (NCSCS).

In accordance with the Government of Canada's Treasury Board Policy, the Treasury Board Secretariat administers the FCSI, where federal organizations (custodians) are required to report specified data on their known or suspected contaminated sites. Each reporting organization is responsible for their own data in the FCSI and maintaining their own internal records.

The FCSI displays a standard set of basic and annually-updated information for federal contaminated sites. Each site record includes information such as the location of the site, the severity of contamination, the contaminated medium, the nature of the contaminant, progress made to date in identifying and addressing contamination, and how much liquid and solid-based media have been treated. The FCSI offers a variety of search criteria, such as site name, province or territory, Census Metropolitan Area, Federal Electoral District, and contaminants; the results can be displayed as a table or on an interactive map.

The FCSI complements the Federal Contaminated Sites Action Plan (FSCAP) and assists the federal government in setting work plans and prioritizing sites for remediation. The objective of FSCAP is to reduce environmental and human health risks from known federal contaminated sites and associated federal financial liabilities, while focusing on highest priority sites. The FCSI assists the development of strategies for individual contaminated sites by informing decision makers on which types of approaches should be taken to address contamination.

Information contained in the FCSI also enables the Treasury Board of Canada to assess departmental performance in implementing the FSCAP through the integration of real property and financial information and linkages to program objectives. The assessment of departmental performance allows the Secretary of the Treasury Board to make recommendations to the deputy head of a department and to Treasury Board. These recommendations may result in an increase in transactional approval limits to acknowledge improved performance or capacity, or conversely, a decrease in authorities in the event of performance falling short.

In Quebec, information on contaminated sites is managed in the système de gestion des lieuxcontaminés (GTC). In general, the data in the GTC system is used to better understand contaminated sites in order to develop guidance and to provide the government with strategic information such as reports, statistics, thematic maps and lists. The database is available online at: www.environnement.gouv.qc.ca/sol/terrains/terrains-contamines/recherche.asp.

<Switzerland>

In Switzerland, inventories play an important role. In particular as a basis for the further processing of a polluted site. Currently, all cantons have completed their inventories (called "catasters" or "registers") and made them available online.

A site does not have to be examined before it is entered in the register. A high probability of a contamination is sufficient for an entry. Where possible, the entries in the register shall contain the following information:

- a.location;
- b.type and quantity of waste delivered to the site;
- c.period of disposal of waste, period of operation, or time of accident;
- d.investigations and measures already taken for the protection of the environment;

- e.effects that have already been ascertained;
- f.endangered environmental areas;
- g.particular events such as waste incineration, landslides, floods, fires or major accidents.

There is an enforcement aid for the creation and maintenance of the register.¹⁴Among other things, it contains industry-specific decision trees for deciding whether a polluted site must be entered in the register or not. (E.g. timber industry: p. 45).

Prioritization for further action on contaminated sites based on risk assessment

<Canada>

The FCSAP takes a risk-based approach to addressing contaminated sites in Canada. This approach involves assessing the risks to human health and the environment of each site and prioritizing the allocation of resources within federal custodians to deal with highest priority contaminated sites.

Information about the 10-step process used to assess, classify, and manage federal contaminated sites is outlined in the guidance document A Federal Approach to Contaminated Sites¹⁵. A decision-making framework¹⁶ was developed to assist federal custodians and their consultants in making the most informed decisions at each step of the 10-step process.

Federal contaminated sites are classified and prioritized based on the NCSCS and the Aquatic Site Classification System (ASCS) developed by FCSAP. The FCSAP Secretariat provides scientific and technical assistance that allows custodians to prioritize their contaminated. Using the NCSCS and ASCS, priority is assessed by scoring sites as high (with a score of 70 - 100), medium (with a score of 50 - 69.9), or low risk (with a score of 37 - 49.9), according to their current or potential adverse impacts to human health and/or the environment. The NCSCS guidance document is available at: https://www.ccme.ca/en/resources/contaminated_site_management/management.html

<Switzerland>

In Switzerland, the authorities must prioritise both the investigation and the remediation of contaminated sites based on a risk assessment:

For contaminated sites in need of investigation, the authorities must establish a priority order for the investigations. In doing so, they take into account the type and quantity of waste at the site, the likelihood of releasing pollutants and the importance of the environmental areas (receiving environments) affected.

In the case of polluted sites requiring remediation, the objectives and urgency of the remediation are determined by a detailed investigation. In particular, the following information must be determined and evaluated in a risk assessment:

- type, location, quantity and concentration of the environmentally hazardous substances at the polluted site;
- type, load and temporal development of the existing and possible impacts on the environment;
- location and importance of the environmental areas at risk.

Further information:

<https://www.bafu.admin.ch/bafu/en/home/topics/contaminated-sites/info-specialists/remediation-of-contaminated-sites/contaminated-sites-management---step-3--detailed-investigation.html>

The interface between contaminated site policies and land use planning policies

<Canada>

¹⁴<https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/etablissement-du-register-sites-pollues.html> (in French)

¹⁵<https://www.canada.ca/content/dam/eccc/migration/fcs-scf/8DF3AC07-5A7D-483F-B263-6DE03104319A/faaf-eng.pdf>

¹⁶<https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites/decision-making-framework.html>

The federal Treasury Board Secretariat's (TBS) Policy on Management of Real Property¹⁷, dictates the federal government's land use planning. It states that known and suspected contaminated sites are assessed and classified and risk management principles are applied to determine the most appropriate and cost-effective course of action for each site. Priority must be given to sites posing the highest human health and ecological risks. Management activities (including remediation) must be undertaken to the extent required for current or intended federal land use.

Quebec's Land Protection and Rehabilitation Regulation established thresholds for contaminants in soil, including mercury, that are dependent on intended land use (e.g. agriculture, residential, commercial or industrial). Based on the intended land use, these limits are also used as the objective of restoration activities. The Regulations may be found at:
www.legisquebec.gouv.qc.ca/fr/ShowDoc/cr/Q-2,%20r.%2037/

<Switzerland>

The coordination with the structure and land use planning is specified in art. 6a of the Swiss Contaminated Sites Ordinance (CSO): The authorities shall take account of the Register in their structure and land use planning.¹⁸

The legal basis for construction projects and contaminated sites is defined in art. 3 of the CSO¹⁹

Polluted sites may be modified by the construction or alteration of buildings and installations only if:

- a. they are not in need of remediation and the project does not make their remediation necessary; or
- b. their later remediation is not seriously hampered, or, insofar as they are modified by the project, they are remediated at the same time.²⁰

There is also an enforcement aid on this topic.²¹The conditions and procedures listed in this publication must be adhered to for construction projects on top of polluted sites.

Existing procedures for the characterization of contaminated sites, including approaches and techniques for sampling and analysis

<Canada>

The CCME has a number of guidelines available for environmental site characterization and approaches to sampling and analysis of contaminated sites, which are available at:
https://www.ccme.ca/en/resources/contaminated_site_management/assessment.html

The Government of Canada also developed the Guidance and Orientation for the Selection of Technologies (GOST) tool to provide guidance to contaminated sites managers on best approaches for site management. The GOST tool can assist contaminated sites managers by providing: the average cost for the analysis of a laboratory sample, a glossary of contaminants and decontamination technologies, as well as a range of resources related to decontamination and the environment. More information on GOST is available at: <http://gost.tpsgc-pwgsc.gc.ca/index.aspx?lang=eng>

In Quebec, site characterization, sampling, and lab analyses must be carried out according to the Guide de caractérisation de terrain. This guide also suggests contaminants that are likely to be found in soils and water by activity or industrial sector using SCIAN cod using the Système de Classification des Industries de l'Amérique du Nord (SCIAN) codes. More information may be found at the links below:

- Site characterization:
www.environnement.gouv.qc.ca/sol/terrains/guide/guidecaracterisation.pdf.
- Evaluation of sediment quality and applications to prevention, dredging, and restoration:
www.planstlaurent.qc.ca/fileadmin/publications/diverses/Qualite_criteres_sediments_f.pdf

¹⁷ <http://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=12042>

¹⁸ <https://www.admin.ch/opc/en/classified-compilation/19983151/index.html#a6a>

¹⁹ <https://www.admin.ch/opc/en/classified-compilation/19983151/index.html#a3>

²⁰ <https://www.bafu.admin.ch/bafu/en/home/topics/contaminated-sites/info-specialists/remediation-of-contaminated-sites/contaminated-sites-management---step-4--remediation/remediation-with-or-without-construction-project--coordinating-c.html>

²¹ <https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/projets-de-construction-et-sites-pollues.html> (in French)

- Sampling methods: www.ceaeq.gouv.qc.ca/documents/publications/echantillonnage.htm.
- Laboratory methods: www.ceaeq.gouv.qc.ca/methodes/list_sols.htm.

<Switzerland>

In Switzerland, the investigation of a polluted site normally consists of a historical and a technical investigation.

The technical investigation determines whether the polluted site has harmful or annoying effects on the protected natural goods groundwater, surface water, soil or air.

The Swiss Contaminated Sites Ordinance (Annexes 1 to 3) contains concentration values for various pollutants for the assessment of these four protected natural goods.²²

There is an enforcement aid for measuring methods for waste and contaminated sites.²³ It contains instructions and prescriptions for the investigation of solid and liquid samples taken from waste or contaminated sites. It describes the state of the art in the field of waste and contaminated site analysis.

Specific enforcement aids exist also for sampling the protected natural goods groundwater and air.²⁴

The existing range of proven and emerging remediation techniques, including situations in which certain techniques may or may not be appropriate, environmental advantages and drawbacks and costs

<Canada>

Guidance and Orientation for the Selection of Technologies (GOST) (PSPC/NRC, 2012; Registration required) for the treatment of mercury contaminated water, soil and sediments²⁵ can help contaminated sites manager to determine the applicable decontamination technology(ies) for specific sites, or, more generally, compare key elements of the decontamination technology or various contaminants.

<Switzerland>

In Switzerland, different remediation techniques are in use. For the different in situ remediation techniques a specific implementation aid exists.²⁶

The mercury contamination in the soils near Visp in the canton of Valais is currently the only large Hg-case in Switzerland. Here, the contaminated material is excavated (in residential areas: soil > 2 mg Hg /kg) and is firstly treated in a soil washing facility; afterwards depending on the contamination level it is put either to landfill or to thermal treatment.

Socioeconomic and cultural considerations during the remediation of contaminated sites

<Canada>

Risk management for contaminated sites is a balancing act of many diverse factors. Each site is managed on a case-by-case basis due to unique site-specific features that require evaluation of risk management approaches in order to choose the most appropriate and cost-effective plan of action. The NCSCS uses a weighted approach to evaluation of contaminated sites, where a significant weight is given to the reliance of local people on natural resources for survival (i.e. food, water, shelter, etc.) which complements the human exposure evaluation section. This inclusion acknowledges potential risks associated with socioeconomic conditions and cultural practices.

<Switzerland>

In major remediation cases, transparency and participation are essential for the population. In particular, health concerns of the local population must be addressed.

²²<https://www.admin.ch/opc/en/classified-compilation/19983151/index.html#app1>

²³ <https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/methodes-analyse-domaine-dechets-sites-pollues.html> (in French)

²⁴ <https://www.bafu.admin.ch/bafu/fr/home/themes/eaux/publications/publications-eaux/prelevements-eau-souterraine-relation-sites-pollues.html> (in French)

<https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/air-interstitiel%20.html> (in French)

²⁵ http://gost.irb-bri.cnr-cnr.gc.ca/hm.aspx?ind_lang=en

²⁶ <https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/assainissement-in-situ.html> (in French)

In the Hg-case in Visp in the canton of Valais, in addition to the usual investigations of the soil, groundwater, surface water and air, a wide range of additional research campaigns were carried out; for example:

- the food and feed plants in fields and gardens were also analyzed
- an epidemiological study was carried out on the local population (analysis of Hg in blood and hair).²⁷

Furthermore, since the beginning of the investigations there is a platform with regular meetings between the authorities, experts, industry, NGOs and the local population.²⁸

Switzerland has to face complex contaminated sites (without mercury) that cost hundreds of millions of Swiss francs to remediate. A guide to understand these complex sites has been developed.²⁹ It takes into account social, political, communication and other aspects.

Information on approaches to financing work on and building capacity for the identification, assessment, remediation and risk management of contaminated sites, including frameworks for domestic financing

<Canada>

As mentioned above, the FCSAP, a 15-year, \$4.54 billion program that was established in 2005 by the Government of Canada, aims to reduce the liability at federal contaminated sites which pose the highest risks to human health and the environment, through remediation and risk management.

Remediation activities have been conducted at 2,170 sites and assessment activities were conducted at 10,840 sites across Canada, since the establishment of the program (as of March 2018).

FCSAP provides three types of funding: 1) assessment; 2) remediation and risk management; and 3) program management. Assessment and remediation/risk-management funding allow custodians to perform work at contaminated sites. Program management funding is provided to assist custodians with the management of their site portfolios through activities such as procurement, contract management, expert support and reporting.

To receive FCSAP funding, federal custodians must ensure that their sites meet funding-eligibility requirements. Therefore, custodians must first have grounds to suspect that a site is contaminated (normally based on historical activities at the site) before environmental site-assessment activities can be funded. The FCSAP Secretariat has developed a prioritization tool to assist custodians in determining the priority of sites that should undergo assessment, considering that funds or resources might not be available to assess all sites at the same time. Guidance on the eligibility of project costs ensures that remediation or risk-management activities focus on reducing risks associated with contaminants.

FCSAP provides funding to custodians for the remediation of sites that:

- Meet the Treasury Board definition of a contaminated site;
- Have been contaminated through activities that occurred prior to April 1, 1998;
- Are on lands owned or leased by the federal government (or if it is non-federal lands, the federal government must have accepted full responsibility).
- Have a financial liability associated with the site (reported within the FSCI)

The province of Quebec has two programs that can assist in financing work on contaminated sites. The ClimatSol-Plus fund encourages restoration and reutilization of contaminated sites located on municipally owned or privately owned properties (for which the province is not responsible for the contamination) www.environnement.gouv.qc.ca/programmes/climatsol-plus/index.htm. The program InnovEnSol offers financial solutions for innovative decontamination businesses for soil and

²⁷ https://www.vs.ch/documents/19415/1246066/Gutachten_Gesundheit_20.06.2016.pdf/775f7148-b1f0-430b-b9f8-0383e9fff95e (in German)

²⁸ <https://www.vs.ch/fr/web/sen/dokumentation> (in French)

²⁹ <https://www.bafu.admin.ch/bafu/fr/home/themes/sites-contamines/publications-etudes/publications/gestion-projets-assainissement-complexes.html> (in French)

groundwater. This program aims to reduce the environmental impacts of contaminated sites, notably by the in-situ treatment and valorization of sediments.³⁰

<Switzerland>

In Switzerland the polluter has to bear the costs of remediation – polluter-pays-principle. If there is more than one polluter in a remediation case, each bears the cost in proportion to his share of responsibility. Thus, the polluter is primarily liable, and the owner only secondarily.

There is no joint and several liability between the polluter(s) and owner(s). Thus, in remediation cases where the polluter cannot be called upon to bear the costs (in cases where the company does not exist anymore or is in failure), the remediation costs cannot simply be passed on to the owner or the other parties involved. Any shortfalls that arise in such cases must be borne by the community. In such cases, and in the remediation of landfills for municipal waste or shooting ranges, the canton can request partial repayment of 30 or 40% of the remediation costs from the federal government on the basis of the Ordinance relating to Charges for the Remediation of Contaminated Sites (OCRCS, in French: OTAS).³¹

This Ordinance stipulates that the requisite funds are to be raised by means of a charge on the disposal of Swiss wastes in landfills in Switzerland and abroad in case of export of waste. This financing instrument is designed to enable dangerous contamination to be cleaned up as quickly as possible and not passed on to future generations for lack of funds. The Ordinance also promotes the environmentally sound and economical remediation of contaminated sites in accordance with the current state of technology.³²

Soil contamination threshold in Iran

Mercury (Hg) (mg/kg)	(7 < pH)	Land Use					Environmental protection (mg/kg)	Groundwater protection (mg/kg)
		Residential	Industrial	park	Agriculture	Rangeland and forest		
		5	30	5	5	5		
Mercury (Hg) (mg/kg)	(7 > pH)	Land Use					Environmental protection (mg/kg)	Groundwater protection (mg/kg)
		Residential	Industrial	park	Agriculture	Rangeland and forest		
		15	55	55	7	5	12	10

³⁰ www.environnement.gouv.qc.ca/programmes/innovensol/index.htm

³¹ <https://www.admin.ch/opc/en/classified-compilation/20071746/index.html> (in English)

³² <https://www.bafu.admin.ch/bafu/en/home/topics/contaminated-sites/info-specialists/financing-remediation-of-contaminated-sites/bearing-the-costs.html>
<https://www.bafu.admin.ch/bafu/en/home/topics/contaminated-sites/info-specialists/financing-remediation-of-contaminated-sites/what-is-the-ocrcs-contamination-fund-.html>

Diagram of Soil Pollution Atlas in Iran

