HARYANA STATE POLLUTION CONTROL BOARD
C-11, SECTOR-6, PANCHKULA
Ph-0172-577870-73, Fax No. 2581201
E-mail: hspcbhazardouswaste@gmail.com

HSPCB/HWM/2022/ Dated: 17/05/2022

To

1. The Branch Incharges (dealing with consent management).
2. All the Regional Officers.

Subject: Supporting Documents for 'Identification & Assessment of Contaminated Sites or Probable Contaminated Sites'in compliance to the directions of Hon'ble NGT order dated 29.01.2021 in O.A. No. 804 of 2017 in the matter of Rajiv Narayan & Anr. Vs. Union of India & Ors.- reg.

Please find enclosed herewith a copy of Email dated 05.05.2022 received from CPCB, Delhi regarding Supporting Documents for 'Identification & Assessment of Contaminated Sites or Probable Contaminated Sites'in compliance to the directions of Hon'ble NGT order dated 29.01.2021 in O.A. No. 804 of 2017 in the matter of Rajiv Narayan & Anr. Vs. Union of India & Ors for information and further necessary action.

DA/As above

Endst. No. HSPCB/HWM/2022/ Dated: 17/05/2022

A copy of the above is forwarded to Sr. Env. Engineer, IT Cell, HSPCB for uploading the above documents on the website of the Board please.

DA/As above

Signed by Naveen Gulia
Date: 17-05-2022 11:27:26
Reason: Approved

Sr. Environmental Engineer (HQ)
For HSPCB

1983663/2022/HWM Br

Gmail hspcb hazardouswaste <hspcbhazardouswaste@gmail.com>

Supporting Documents for 'Identification & Assessment of Contaminated Sites or Probable Contaminated Sites'in compliance to the directions of Hon'ble NGT order dated 29.01.2021 in O.A. No. 804 of 2017 in the matter of Rajiv Narayan & Anr. Vs. Union of India & Ors, reg

1 message

Contaminated Sites <remediation.cpcb@gov.in> Thu, May 5, 2022 at 12:09 PM
To: Member Secretary APPCB <membersecy@appcb.gov.in>, membersecretary@pcbassam.org, hocecb@gmail.com, Member Secretary <msdpcc@nic.in>, Member Secretary GSPCB <ms-gspcb.goa@nic.in>, membersecretarygpcb@gmail.com, ms-gpcb@gujarat.gov.in, Haryana Pollution Control Boar <hspcb@hry.nic.in>, mshspcb@gmail.com, mspcb-hp <mspcb-hp@nic.in>, mshppcb@gmail.com, ranchijspcb@gmail.com, Head office Karnataka State Pollution Control Board <ho@kspcb.gov.in>, Srinivas ulu <ms@kspcb.gov.in>, Sreekala S <ms.kspcb@gov.in>, lt mppcb <lt_mppcb@rediffmail.com>, ms msoffice <ms-mppcb@mp.gov.in>, ms@mpcb.gov.in, membersecretary@ospcboard.org, Member Secretary PPCB <msppcb@punjab.gov.in>, msppcb@gmail.com, Member Secretary <member-secretary@rpcb.nic.in>, MS TNPCB <memsec@tnpcb.gov.in>, ms-tspcb@telengana.gov.in, ms@uppcb.com, msukpcb@yahoo.com, msukpcb@gmail.com, RAJESH KUMAR <ms.wbpcb-wb@bangla.gov.in>, ABHIJIT BASU <spm.wbpcb-wb@bangla.gov.in>, mspcbwb@gmail.com, H D VARALAXMI SEE CPCB <vlaxmi.cpcb@nic.in>, Suresh Sathyanarayana <ssuresh.cpcb@nic.in>, Pentani jagan <jagan191.cpcb@gov.in>, gurnam <gurnamsingh.cpcb@nic.in>, Mrinal Kanti Biswas <mkbiswas.cpcb@nic.in>, "rksingh.cpcb" <rksingh.cpcb@nic.in>, BHARAT KUMAR SHARMA <bksharma.cpcb@nic.in>, PRASOON GARGAVA <prasoon.cpcb@nic.in>, Mantu Kumar Choudhury <mkc.cpcb@gov.in>
Cc: Vijay yadav <vpyadav.cpcb@nic.in>, G Rambabu Scientist D <grbabu.cpcb@nic.in>, Gargi Biswas <gargib.cpcb@gov.in>, "Nagarjuna .M" <unit4-ee1@appcb.gov.in>, "Satyanarayana .E" <unit3-ee3@appcb.gov.in>, Sangeeta bhole <henv.cg@gov.in>, "P.S.Pankaj Env.Engineer" <pspankaj.dpcc@gov.in>, Goa PCB <mail.gspcb@gov.in>, "Environment Engineer GSPCB, Goa" <ee-gspcb.goa@nic.in>, uh-gpcb-hazw@gujarat.gov.in, hspcbho@gmail.com, hspcbhazardouswaste@gmail.com, hwm kspcb <hwm.kspcb@gmail.com>, Regional Officer Dasarahalli KSPCB <dasarahalli@kspcb.gov.in>, sendtosumi@gmail.com, pcbhorulesee3@gmail.com, harshvardhanthakkar007@gmail.com, rohq@mpcb.gov.in, hwmd@ospcboard.org, solab2010@gmail.com, mksingh rpcb <mksingh.rpcb@gmail.com>, see-uh5-tspcb@telengana.gov.in, ngtcell@uppcb.com, dimriniharika@gmail.com, sompals2@gmail.com, SUBRATA GHOSH <ce1.wbpcb-wb@bangla.gov.in>

Sir/Madam,

This has reference to 4th meeting held on 04.05.2022 to review the action plan(s) in compliance to the directions of Hon'ble NGT order dated 29.01.2021 in O.A. No. 804 of 2017 in the matter of Rajiv Narayan & Anr. Vs. Union of India & Ors; w.r.t., Assessment of Contaminated Sites. In this regard, **the link of 02 technical guidelines is shared for kind information and reference**:

1. **Reference Document on Identification, Inspection and Assessment of Contaminated Sites by CPCB** (https://cpcb.nic.in/uploads/hwmd/CPCB_guidelines_contaminatedsites.pdf)
2. **Guidance document for assessment and remediation of contaminated sites in India by MoEF&CC** (https://cpcb.nic.in/uploads/hwmd/MoEFCC_guidelines_contaminatedsites.pdf)

Copy of the aforesaid documents are also enclosed herewith for your kind reference. Further, it is requested to refer
(i) Page No. 211-216 of ***MoEF&CC Guidance document for "Screening level/standard of Soil/Sediment/GW/SW samples"*** and
(ii) Page No. 15-17 of ***CPCB Reference document for "Format of Preliminary Investigation Report on Contaminated Sites (CS) / Probable Contaminated Sites (PCS) & relevant parameters"***.

With regards,

G. Rambabu
Scientist-D (WM-I) & Head, Law Division
Central Pollution Control Board,
(M/o Environment, Forest & Climate Change, GoI),
Parivesh Bhawan, East Arjun Nagar,

Delhi - 110052
Ph.: +91-11-2238 4375 (O)
+91-11-43102325 (Ext.)
+91-8010479108 (M)

2 attachments

CPCB_guidelines_contaminatedsites (2020).pdf
2420K

MoEFCC_guidelines_contaminatedsites (2015).pdf
4801K

Reference Document

on

Identification, Inspection and Assessment of Contaminated Sites

[Based on Guidance document for assessment and remediation of contaminated sites in India, Issued by MoEF&CC]

(June, 2020)

Central Pollution Control Board
(Ministry of Environment, Forest & Climate Change)
Parivesh Bhawan, East Arjun Nagar
Delhi – 110032

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Chapter-1

1.1 Introduction

There are several contaminated dumpsites in various parts of country where hazardous and other wastes were dumped historically, which has most likely resulted in contamination of soil, groundwater and surface water thereby posing health and environmental risks. Most of the contaminated sites were created when industrial hazardous wastes were disposed by occupiers in unscientific manner or in violation of the rules prescribed. Some of the sites were developed when there was no regulation on management of hazardous wastes. In some instances, polluters responsible for contamination have either closed down their operations or the cost of remediation is beyond their capacity, thus the sites remains a threat to the environment. These contaminated sites need to be investigated in detailed and remediated on priority, to levels that are acceptable considering the human health risks and environment by adopting appropriate remediation technologies.

Contaminated sites may include production areas, landfills, dumps, waste storage and treatment sites, mine tailings sites, spill sites, chemical waste handler and storage sites. These sites may be located in residential, commercial, agricultural, recreational, industrial, rural, urban, or wilderness areas. This document deals with different types of contaminated sites in India. Various elements of the assessment process as described in this guideline can be used for remediation of different types of contamination.

Remediation of contaminated sites involves cleaning of contaminated media i.e. soils, groundwater, surface water and sediments by adopting various in-situ or ex-situ clean-up technologies up to a predefined remediation target levels for each identified constituent. Site specific target levels (SSTLs) for remediation are calculated for each site separately adopting either the risk based assessment approach or standard based approach. Risk based SSTLs for remediation can be derived from either quantitative or qualitative human health risk / ecological risk caused by a particular constituent of concern based on source-pathway-receptor scenario of contaminated site.

Various factors influence the selection of remediation technology, such as cost of remediation, type of intended future land use, feasibility of a remediation technology, etc. Technology for remediation is decided after considering all factors. While the legal aspects of the origin of a contaminated site may or may not be clear, the technical issues concerning disposal or dumping remain same for legal or illegal contamination.

1.2 Waste Vs Soil contamination

Uncontrolled dumping of waste and absence of remedial measures leads to soil contamination when it leaches and negatively affects soil or groundwater or other environmental features. Not all wastes automatically lead to soil contamination.
"Soil" is the upper layer of earth comprising of black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. In the context of understanding soil contamination, soil is considered to comprise three phases, including the organisms living in these phases:

- *Solid phase, consisting of the sand, loam, and clay particles, but also including the organic solid elements, like decomposing leaves;*
- *Liquid phase, consisting of the groundwater; and*
- *Gaseous phase, consisting of the air trapped among the soil particles.*

Underwater soil is usually referred as 'sediment'.

Soil contamination can occur in any of these three phases or in any combination thereof. Contamination of the solid phase may be visible; e.g. when hazardous waste has been dumped on top of the soil; or not visible, e.g. when dumped waste was covered. However, contamination of the liquid and gaseous phase is often not clearly visible, and almost always entails specific, sometimes far greater, risks. Factors such as surface run-off, usage, movement, etc. over the contaminated soil often spread the contamination relatively fast, thereby it may contaminate larger volumes of soil, groundwater or air.

1.3 Typology of Contaminated Sites

The following main types of contaminated sites are distinguished based on causing activity and pathway of spreading of contamination:

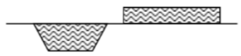
Source related;
- **Type S-1** **:** Land bound solid phase contamination
- **Type S-2** **:** Water bound sediments solid phase contamination
- **Type L-1** **:** Land bound liquid phase contamination

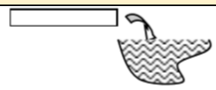
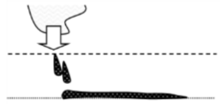
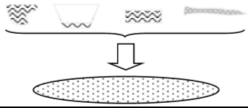
Pathway related;
- **Type P-1** : NAPL contaminants in soil (Non Aqueous Phase Liquids)
- **Type P-2** : Groundwater contamination

The sites can be further classified as per the **Table-1** below:

Table-1: Typology of Contaminated Sites

Type	Description or activity along with typical field characteristics of the site / example	Symbol
S-1	**Land bound Solid phase contamination (land bound site)**	
S1-a	Mixing the soil with wastes or materials containing constituents	

Type	Description or activity along with typical field characteristics of the site / example	Symbol
	of contamination*, not including agricultural activities. Well defined body below surface level defined by boundaries of soil where soil is mixed with contaminants. E.g. This may occur when material containing contaminants are spread over soil and ploughed to mix with soil.	
S1-b	Dumping of wastes or materials containing constituents of contamination over the soil into embankment, filling of pits or depressions or surface waters. Well defined body of non-mixed contaminants. E.g. storage of mine tailings, illegal dumping of hazardous wastes.	
S1-c	Bulk storage of wastes or materials containing constituents of contamination. Industrial activities in which contaminated solids are used. Leftovers of incineration and burning of waste material. Irregular shaped layer of contaminated material, recognizable as such. The shape of the contaminated site is related to the activity leading to the contamination	
S1-d	Adding material containing contamination through agricultural activities (e.g. pesticides, fertilizers or additives to animal feed). Agricultural site bound contaminations found up to a depth to which the soil is treated by ploughs and other agricultural tools.	
S1-e	Atmospheric deposition of emissions or windblown dust including fugitive dust from industries/roads/railways. Thin layered contaminations found over large areas with the highest concentrations close to the source following the prevailing wind direction.	
S1-f	Deposition by flooding or washing. Contaminations found in areas flooded by water systems or in downstream areas of flooding areas. The shape of the contaminated site is determined by the flooding of flow of a water system	
S-2	**Contaminated open water sediments**	
S2	Solid phase contaminants settled from surface water. The shape of the contaminates site corresponds to the shape of the water system itself. Constituents of contamination may be bound to silt, clay or organic compounds of sediments.	
L-1	**Liquid phase contamination* (land bound site)**	
L1-a	Industrial or commercial activities involving handling of fluids such as solvents, lubricants, paint, etc. Liquid contamination in soil situated near a potential source of the contamination.	
L1-b	Storage of liquids that contain contaminants in tanks or barrels (either storage on surface or subsurface). Liquid contamination in soil situated at any place at a liquids storage site.	
L1-c	Transfer and transport of fluids through linear infrastructure such as pipelines, channels. Weak points are couplings, pressure regulators, valves, breakpoints and leakage through foundations / buildings. Liquid contamination in soil situated at any place along a transport piping system or drains.	
L1-d	Spills or leaks of liquids either on surface or in rivers/lakes. This	

Type	Description or activity along with typical field characteristics of the site / example	Symbol
	may possibly lead to type S2 or P2. Liquid contamination in soil situated at the end of a transport piping or drain system	
P-1	**NAPL contaminants in soil**	
P1-a	Dense Non-Aqueous Phase Liquid (DNAPL) in permeable soil where bulk density is more than that of water; Spreading of liquids due to gravity flow resulting in a characteristic spreading pattern. It should be noted that DNAPL's laying of the bottom of an aquifer can result in a secondary source of spreading of type P-2	
P1-b	Light Non-Aqueous Phase Liquid (LNAPL) in permeable soil. (bulk density < water); Spreading of liquids in a characteristic spreading pattern of floating layers. It should be noted LNAPL's laying at the top of a water table can result in a secondary source of spreading of type P-2	
P-2	**Leached or dissolved contaminants in groundwater**	
P2	Groundwater contamination. Due to spreading of leachate or mobile dissolved contaminants in a permeable soil	

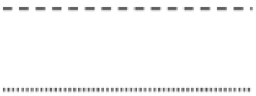
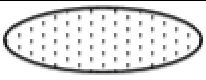
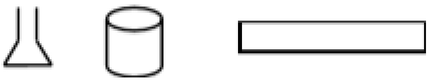
* *Contaminated material may include wastes in Schedule I or the constituents listed in Schedule II of HOWM Rules, 2016. It shall also include constituents listed for screening of contaminated soils as per the guidance document or notification issued by MoEF&CC.*

[a] *A dense non-aqueous phase liquid or DNAPL is a liquid that is both denser than water and is immiscible in or does not dissolve in water. The term DNAPL is used primarily by environmental engineers and hydro geologists to describe contaminants in groundwater, surface water and sediments. DNAPLs tend to sink below the water table when spilled in significant quantities and only stop when they reach impermeable bedrock. Their penetration into an aquifer makes them difficult to locate and remediate. Examples of materials that are DNAPLs when spilled include chlorinated solvents or creosote.*

[b] *Light Non-Aqueous Phase Liquid (LNAPL) is a groundwater contaminant that is not soluble and has a lower bulk density than water, which is the opposite of DNAPL. Once LNAPL infiltrates through the soil, it will stop at the water table. The effort to locate and remove LNAPL is relatively cheaper and easier than DNAPL because LNAPL will float on top of the water in the underground water table. Examples of LNAPLs are gasoline and other hydrocarbons.*

Depending on a specific situation, a contaminated site may have combination of above mentioned types as possible. Example: a land bound storage of chromium containing hazardous waste (type S1), causing leachate of chromium to groundwater and leading to a contaminated groundwater plume (type P2).

Table-2: Key Icons as per Typology of Contaminated Sites

Symbol	Description
	Solid waste or solid waste mixed with soil (all in solid phase). Varying in shape, thickness and extent, depending on local conditions.
	Dashed line: Groundwater table Dotted line: Base of aquifer / top of impermeable layer.
	Liquid waste. Pure or mixed with soil.
	Leaching / spreading of contaminants to soil / groundwater. Depending on permeability of the soil.
	Contaminated groundwater plume. Depending on permeability of the soil.
	DNAPL or LNAPL.
	Spill / leakage of material containing constituents of contamination.
	Related to industrial or commercial process outlets, storage facilities and bulk transfers. (Not soil related human activity / construction)

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Chapter-2

Identification & Verification of Probable Contaminated Sites

2.1 Introduction

Probable contaminated site is defined as "*Sites with alleged (apparent, purported) but not scientifically proven presence of constituents of contaminants or substances caused by humans at concentrations and characteristics which can either pose a significant risk to human health or the environment with regard to present or future land use plan [pattern] or exceeding specific concentrations or guidelines values prescribed for human health and or the environment*"

A probable contaminated may be identified upon collection of information based on any site investigation reports, regulatory records, petitions, public complaints, new reports, etc. A site inspection would be necessary for verification and evaluation of the obtained information.

2.2 Verification Activities

The process of identifying and verifying a probable contaminated site often necessitates the involvement/interaction with local residents & officials, workers, local complainants, stakeholders, and local environmental NGOs including environment and health experts, who may have detailed knowledge of the history of a site and waste dumped at the site or transported to other locations that also may have become contaminated.

Verification of data can be done by collecting information independently from the person or organization responsible for submitting the original petition, report or complaint. Often, a brief site visit may be beneficial to enable a visual verification of the situation by the reviewing team. Interviewing relevant stakeholders usually yields information that will supplement previously collected data.

Probable contaminated sites may be identified without specialized technical equipment by the following means:

- 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 & fauna presumably caused by the proximity to the site;

Once the appropriate data has been obtained and verified, an evaluation assessment of whether or not the site qualifies as a '*Probable Contaminated Site*' may be undertaken.

The evaluation is visualized in the flowchart below:

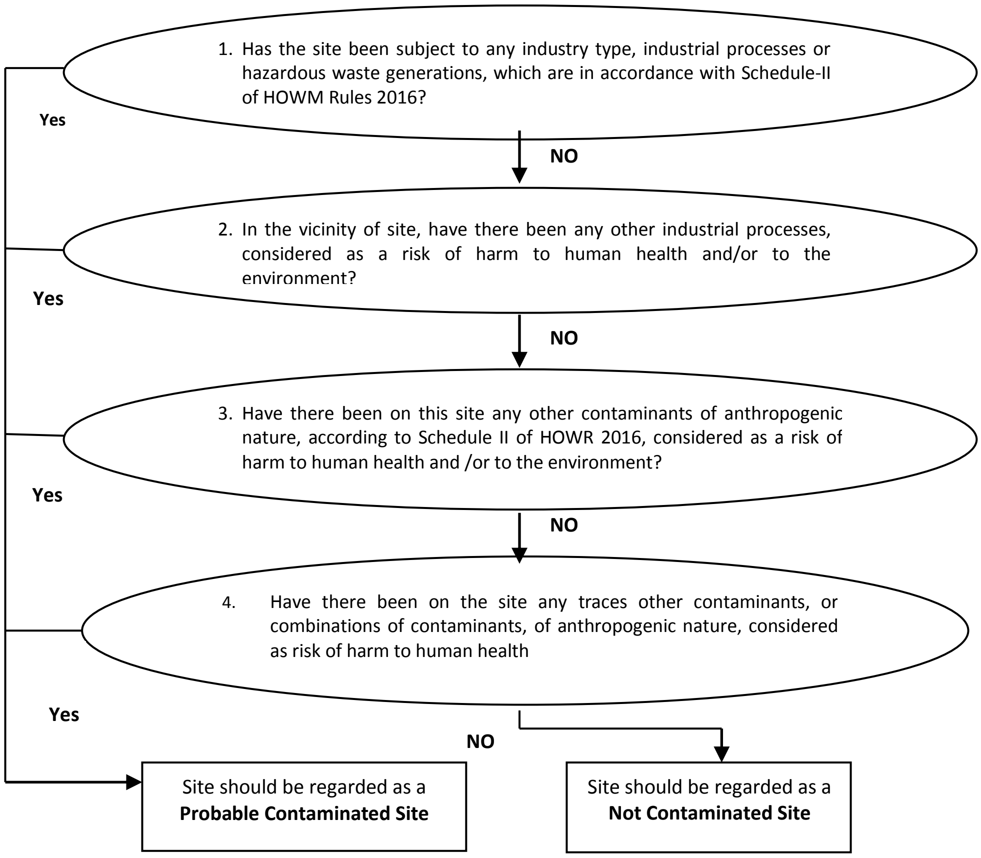

Figure-1.1: Flowchart for evaluation of probably contaminated site

2.3 Outcome

Outcome of the assessment, i.e. identification & verification of the site is to record the conclusion as to whether or not the site is regarded as a probably contaminated site. If so, a preliminary site investigation would be required. If the site does not qualify as a probable contaminated site, it is not necessary to continue Preliminary investigation.

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Chapter-3

Preliminary Site Investigation

3.1 Introduction

The purpose of preliminary site investigation is to establish whether or not a site should be regarded as a contaminated site as defined below:

"Contaminated sites are delineated areas in which the constituents and characteristics of the toxic and hazardous substances, caused by humans, exist at levels and in conditions which pose existing or imminent threats to human health and/or the environment".

3.2 Objectives

(i) To identify the potential for past or current uses & activities at the site and in the immediate vicinity of the unit to have caused contamination of land and groundwater at the site.

(ii) To identify all sources of contamination and the relevant pathways linking them to the receptors of concern.

3.3 Activities during Preliminary Site Investigation

i) Desk study

Desk study shall be carried out on the available information of the site. Information in reports and petitions is assessed and new information shall be inventoried. It is required to have as much information as possible concerning the history and land use both on-site and off-site. The data review may identify gaps in the available data. Additional information can be obtained from maps, data bases or governmental information. The available reviewed information and the newly collected information can be summarized in a table and information gaps should be indicated before the site inspection is carried out.

Based on all the compiled information a work plan should be devised prior to site inspection. The work plan should include all reconnaissance activities and identify the specific information to be collected.

ii) Site inspection

Site inspection is to be carried out to verify the information of desk study and to prepare a plan for sampling and testing. During site inspection information is obtained to fill the gaps and existing available information is to be verified (refer ***Section-3.4***). If possible photographs should be taken. The site inspection needs to be prepared by arranging access to the site and in consultation with important stakeholders. Furthermore, equipment, e.g. for sampling, needs to be prepared. The information gathered during the site inspection should be summarized in tables and a sketch map should be drawn showing the principal recorded occurrences and expected sources of contamination the main exposure and migration pathways of pollutants and the locations of receptors.

iii) Investigation strategy

The potential sources, pathways and receptors of concern should be established based on previous reports or petitions, maps, records, aerial photographs and interviews with owners or other informed parties. At the locations where main sources of contamination and relevant pathways to possible affected receptors are expected limited sampling and testing is to be carried out. During activities of the fieldwork, focus on locations where the highest contaminant concentrations have been expected and the locations of the most sensitive land use. Need to also understand the lateral vertical extent of impact to soil and groundwater.

If additional site specific information is available, the general type can be made more site-specific by developing a Conceptual Site Model (CSM). The CSM supports the investigator to visualize the possible sources, pathways and receptors relevant at the site.

Based on the investigation strategy an investigation work plan shall be prepared, regarding assessment of the contamination levels of the source and identification of the major pathways and receptors of concern. This work plan should pay attention to the following elements:

a) Sampling pattern

Knowledge of the possible location of contamination sources is important for defining the sampling pattern. Small areas where contaminated material is concentrated in one place (point source contamination) can be investigated during the preliminary site investigation by a few representative samples collected from one or two exploratory excavations.

In case contaminated material is spread over a large area it is necessary to use a pattern of samples to collect representative information of the contaminated site.

b) Sampling protocol as well as screening and response level for contaminants with respect to contaminated site

- **Determination of background levels:**

  Soil samples for determining background level should be collected from 2 different locations (separated by minimum distance of 500 m) each at 3 orthogonal directions (excluding downstream direction) at a distance beyond 2 km from the contaminated site boundary. If the contamination is observed at the investigation background site during, or prior to determination of background levels, then sampling location should be selected beyond 5 km distance. Depth of the sampling (Background levels) should be at the same intervals as adopted for the contaminated site.

- **Determination of contamination levels:**

  A minimum of 5 locations in plan (4 near the corners/perimeter), and one at the centre of the probable contaminated area in plan would be taken up. For large areas (e.g. 500 m x 500 m or more) where spacing between sampling locations would exceed 150 m, intermediate locations would be also identified (preferably in a square grid of 150 m X 150 m). For diffused contaminated area, number of samples should be proportional to the area of contaminating activity and sampling points should be spread enough to represent the area.

Sampling will be done at each location at the depths of 0.5, 1.5 and 3.0 m respectively in boreholes or pits (dry drilling methods). If probable contamination is deeper or has reached ground water, sampling will be done in boreholes after 3.0 m depth at every additional 1.5 m depth. Sampling below water table will be done by dry drilling methods followed by undisturbed soil sampling. When boreholes are being advanced, a trained geologist should be present on-site to prevent vertical or lateral cross contamination.

Undisturbed soil samples (whole samples) will be collected in stainless steel sampling tubes (or sampling tubes with inner liner) with a diameter between 25 to 100 mm (or equivalent), which are pushed or driven into the soil. Sampling tubes will be sealed at both ends (with the caps) at the field when tubes are withdrawn from the soil. These sealed tubes will be de-sealed for testing in the laboratory.

If probable source of contamination is observed on site, or nearby area such as accumulation of solid waste or effluent discharge point atleast 3 samples will be collected and analyzed.

- **Groundwater sampling and analysis:**

  Groundwater sampling and analysis shall be done at the site if water table is encountered within depth of 25 m; 3 samples will be taken after successive purging. If groundwater table is deeper more than 25 m, then groundwater sampling should be done by collecting samples at each nearby existing borewell/monitoring well within a radius of 2 km. Installation of groundwater monitoring wells is necessary to establish groundwater flow direction and gradient.

- **Surface water analysis:**
  Surface water quality should be examined by collecting and analyzing at least 3 samples each from water bodies (such as stagnant, flowing/drain/pond etc.) located within the range of 1 km from the contaminated site.

- **Sediment sampling:**
  (i) To collect a sediment sample from a water body or other surface water conveyance, following methods can be used:
    - Scoops and spoons
    - Dredges (Ponar, Young)
  (ii) Samples will keep in several pp-zipped packs/ wide mouth glass bottles.
  (iii) If the total VOC concentration in the sediment is expected to be less than 200 µg/kg, the samples may be collected directly with the sampler and the sample must be placed in the sample container (40 ml pre-prepared vial*) immediately to reduce volatilization losses.

  *[*The pre-prepared 40 ml vials should contain 10 ml of organic-free water for an un-preserved sample. It is recommended that the 40 ml vials be prepared and weighed by the laboratory.*

- **Quality assurance/Quality control:**

  Collect duplicate and split samples along with a field blank sample. For the quality assurance, Certified Reference Materials (CRM) for the analysis of soil parameters should be used, wherever these are required and available.

There are some additional aspects that should be taken into account when developing a sampling strategy for a specific site:

- Restrictions for investigation such as buildings, subsurface infrastructure and site boundaries;
- If possible some samples should be obtained for identification of background quality of soil, groundwater, sediment or surface water which has not been influenced by this particular contamination;
- Samples of groundwater may be obtained from selected existing observation wells in the aquifer beneath the surface of the site, for monitoring water level elevation and water quality at appropriate locations. The depth of the well and the filter (if any) should be known. If there is data from previous sampling or level measurements it is important to know the frequency and period relating to the hydrological environs (influence of monsoon).

c) Parameters for laboratory testing

The parameters significant for the investigation can be selected based on:

- Previous industrial operation processes or waste generation, discharges or disposal activities.
- Specific observations during site inspection and field work of signs which indicate contamination not related to the above mentioned activities.
- It is always recommended to test some samples for a broad spectrum of parameters (refer ***section-3.5***). As it is possible that there may have polluting activities at the site those are either unknown or not documented. Such activities may possibly cause contamination with different characteristics compared to the known activities.

iv) Fieldwork, sampling and testing

An initial assessment of contamination present at the site may be ascertained from samples taken during the site inspection. These samples should be obtained from locations where the main sources of pollution are expected, and at locations within migration pathways. Because only a limited number of samples are obtained, the sample locations should be well chosen, and guidance for possible locations for sampling of sources and pathways:

- Visual indication of cause of pollution such as the presence of (former) industrial process equipment, storage tanks, broken pipelines, etc;
- Visual evidence of hazardous material by means of colour or odour or the composition of material, or uneven ground surface;
- Reported location with confirmed high concentration levels in previous sampling results;

- Where an incident (spill / uncontrolled release) has occurred identified by a former employee of a company;
- Areas which can easily be accessed by humans and areas of sensitive use (residential, playground, agriculture);
- Drinking water wells downstream of the site (to collect groundwater samples to assess if this pathway is contaminated);
- Surface water at or near the site if expected to be contaminated by hazardous waste material;
- At discharge points with noticeable contamination an effluent sample should be taken;
- In cases of sites with effluent discharges a 'source sample' should also include a sample of the sediment.

The samples should be tested in a laboratory to assess the levels of contamination in the sample. Laboratories should operate in accordance with specific accreditation criteria.

The parameters for determination within each sample scheduled for analysis will depend on the hazardous waste material potentially present. For the various activities representative tracer components have been described. The tracer components can be seen as components of concern. If there is existing information about contaminants from previous investigations, this information should be used to select tracers. It has to be stated that not all the listed tracers necessarily have to be analysed at a site, but the list can be used as a starting point for the assessing analysis program at a specific site.

The descriptions should be accompanied by sketches of the site (location of sources, dimensions, distances to receptors, significant site features, with marking of north and scale. The locations of exploratory holes should preferably be indicated by XYZ- coordinates, using GPS.

v) Comparing testing results with levels/standards

The laboratory test results should be tabulated and recorded in terms of concentration levels for each parameter / substance per sample. Analysis results to be compared with the Screening & Response levels/standards, (if applicable) and a conclusion are drawn as to whether or not the site should be regarded as a contaminated site.

All the above activities are illustrated as flowchart at **Figure-3.1** for the comparison of concentration levels with Screening and Response levels. In some areas the natural background levels may be higher compared to the Screening levels, e.g. the natural background levels of metals and other inorganic chemicals can vary widely and this should be taken into account when applying the Screening levels. Where it can be demonstrated that natural background concentrations are elevated (e.g. heavy metal concentrations in mineralized areas), it would be appropriate to develop less stringent assessment criteria. However, care needs to be taken when historic mining and/or waste disposal activities may influence establishing the level of the natural background.

vi) Reporting and review

Details of all activities shall be carried out, the results of the preliminary site investigation should be included in the site investigation report. In the preliminary site investigation report all major sources, pathways and receptors of concern should be identified. It is significant to recognize if there are indications of on-going hazardous waste generation or fresh waste disposal or discharge on the site.

Furthermore, the initial Conceptual Site Model (CSM) should be reviewed and probably adjusted based on the results of the preliminary site investigation. If enough data is available groundwater level contour maps may be developed in order to indicate the groundwater flow direction. When interpreting the results of groundwater quality, the possible influence of seasons should be taken into account.

The investigating agency should ensure appropriate quality assurance protocols and systems have been adhered to including prescribed protocols, the calibration of field instruments, proper sampling and collection techniques and by providing records of responsibility, non-conformity events, corrective measures and data deficiencies.

3.4 Outcome

Output of preliminary investigation is the conclusion as to whether or not the site is qualified as a contaminated site. If so, detailed site investigation would be required. If the site does not qualify as a contaminated site, it is not necessary to continue detailed investigation of the site.

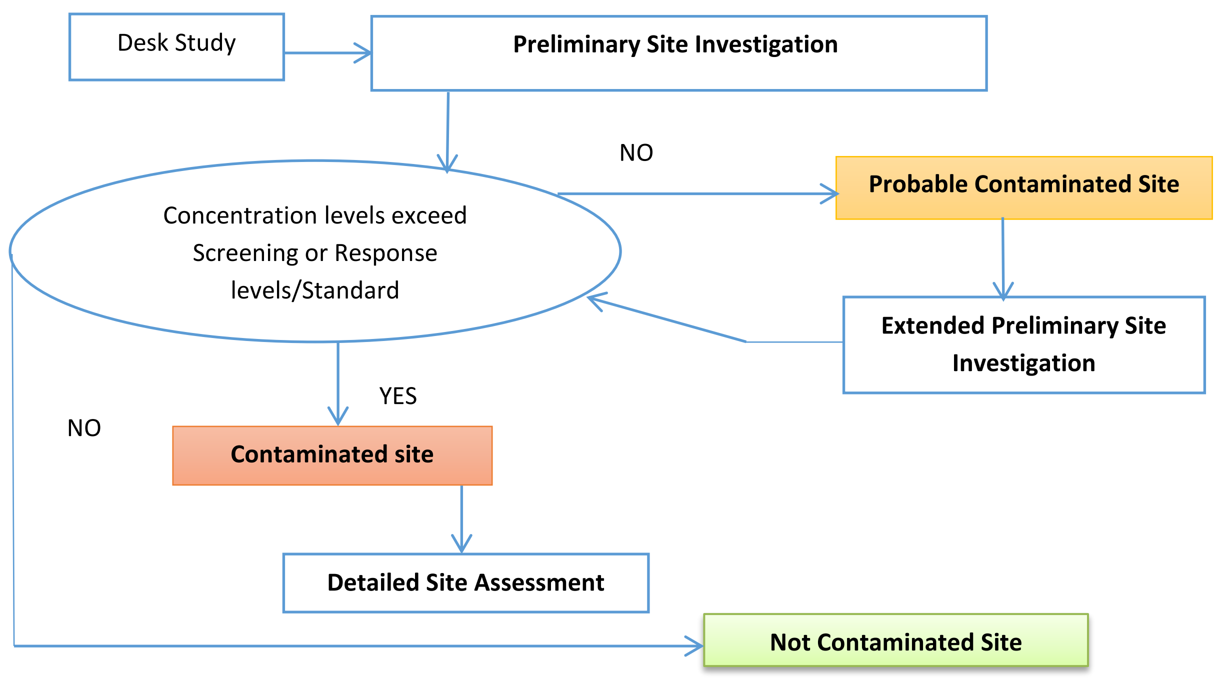


Figure-3.1: Flowchart for Identification & Assessment of site investigation

3.4 Format of Preliminary Investigation Report on Contaminated Sites (CS) / Probable Contaminated Sites (PCS)

1.	Name of the Site	:	
2.	GPS Co-ordinates	:	
3.	Nature of Sites: CS/PCS (as submitted before Hon'ble NGT)	:	
4.	Names of the Inspection Team members with Designations	:	
5.	Date of Inspection	:	
6.	Possible sources of contamination due to present/ past land-use or other activities at the site	:	
7.	Chemical of Concerns (CoCs) as per information provided by CPCB	:	
8.	Other possible chemicals of concerns (CoCs) other than specified at **S. No. 7**.	:	
9.	Name of the Polluter(s) (if identified) and detail address with contact number and e-mail address / Orphan Site	:	
10.	Present land use (Agricultural/ Residential/Commercial/Industrial) or other activity at the site	:	
11.	Present use / activities in the immediate vicinities of the site.		
12.	Present ownership of the site (detailed address with contact number and e-mail id)	:	
13.	Distance of important features around **0.5 km** radius of the site	:	Details with distance from the site

	- Habitation		
	- Industry / Mine		
	- Land use		
	- Surface water bodies		
	- River / Streams, etc.		
	- National/State Hihways/ Ports / Railways		
	- Educational Institutions		
	- Places of worship		
	- Ground water withdrawal		
	- Others (please specify)		
14.	In case of sources contamination is not known, extend the study area to at least **0.5 km** radius with collection of more numbers of samples		
15.	Soil samples collected with their locations from the site and land use	:	
16.	Surface water and sediment samples collected with their locations from the site and present usages of surface water	:	
17.	Ground water samples collected with their locations from the site and present usages of ground water.	:	
18.	Possible migration of contaminants from source of contamination at the site (such as legal or illegal dumping of wastes, spillage during transportation, carry over with surface water and/ rain water, abandoned industrial activity,	:	

	etc.), as specified at **S. No. 6**		
19.	In case of sources contamination is not known, extend the study area to at least 0.5 km radius with collection of more numbers of samples	:	
20.	Comment if the site poses existing/imminent threat to human health and the environment or to property with regard to present or future land use and site activity	:	
21.	Comment if immediate removal of waste (optional contaminated soils/ sediment) is warranted for disposal in the CHWTSDF or safe storage and approximate quantum of such wastes.	:	
22.	Enclose the followings along with the Preliminary Investigation Report; 1. Samples collected, analysis of the same shall be done for chemicals of concern (CoCs) along with necessary general parameters and heavy metals. The analysis results shall be compared with screening/response levels. 2. Soil samples may be collected at different possible depths i.e. at surface (0-15 cm), (15-30 cm). 3. Analysis of soil samples shall be done in total concentration (not in TCLP/WET extraction methods). Correctly indicate the units (mg/kg) in analysis report. 4. Few colour photographs of the site with surrounding features	:	

Signature of the Inspecting Officer(s)

3.5 Parameters for Analysis of Soil/Sediment/Groundwater/Surface water samples

General Parameters		Heavy Metals (HMs)*	Organic Pollutants#
Groundwater/ Surface water	**Soil/Sediment**	**Soil/ Sediment/ Groundwater/ Surface water**	
- pH - DO (mg/L) - TDS (mg/L) - Conductivity (µmho/cm) - Colour (Hazen) - Temperature (°C) - Fluoride (mg/L) - Chloride (mg/L) - Nitrate (mg/L) - Sulphate (mg/L) - Phosphate (mg/L) - Hardness (mg/L) - **COD (mg/L) - **BOD (mg/L) - **Total coliform - O&G (mg/L) # - Cyanide (mg/L) #	- pH - Moisture Content (%) - Organic Matter (%) - Sodium (mg/Kg) - Potassium (mg/Kg) - Calcium (mg/Kg) - Cation Exchange Capacity (meq/100g)	- Arsenic - Antimony - Chromium [Total + (VI)] - Copper - Cobalt - Cobalt - Cadmium - Iron - Lead - Manganese - Molybdenum - Mercury - Nickel - Zinc	- TOC - α-BHC - β-BHC - γ-BHC - Aldrin - Dieldrin - α-Endosulfan - β- Endosulfan - DDT/DDE/DDD - Chloroform - TCE - Chlorobenzene - BTEX

Note:

- Samples collected, analysis shall be done for chemicals of concern (CoCs) along with necessary general parameters and HMs (Further, OCPs for site specific).
- Analysis of heavy metals for soil/sediment samples shall be done in total concentration (*not in TCLP/WET extraction methods for soil/sediment samples**).
- **Only for surface water samples.
- #*Source of contamination specific parameters*: plastic-zipped packs for soil/sediment samples & wide mouth dark colour glass bottles for water samples.
- Unit for Water samples: (mg/L) & Soil/Sediment samples: (mg/kg).
- The analysis results shall be compared with screening/response levels for Soil/sediment samples and standards for water samples.
- Analysis of the soil/waste/sediment/groundwater/ surface water samples will be followed by standard methods of APHA and USEPA and the said samples shall be analyzed in NABL accredited and E(P)A, 1986 recognized labs.
- Analysis results shall be compared with available screening & response levels or standard for soil/ sediment/ groundwater/ surface water, so as to ascertain the level and extent of contamination at the site.
- In case of *Hazardous waste*, the samples shall be compared with Schedule-II of Hazardous and Other Wastes (Management & Transboundary Movement) Rules, 2016 and amended thereof.

Chapter-4

Sampling Tools and Techniques for site investigation

4.1 Introduction

This Section provides an overview of techniques, which are widely used for screening as well as sampling collection techniques. Depending on the situation the field investigation team must use personnel protection equipment. The basic PPEs include boots, protective clothing, dust masks, goggles or safety glasses and hard gloves. This Section is relevant for both preliminary and detailed site investigations.

4.2 Screening Equipment

An overview of technical screening equipment for preliminary site investigation is shown in **Table 4.1**. In cases where the location of the source or the pathway or both is not known, screenings techniques in **Table 4.1** can be used as first step in a Preliminary site investigation. These techniques provide a 'quick and short-cut' approach to assess approximate delineation of the source or pathway or both, which is required for sampling and testing. This table only shows generic techniques. The selection of techniques should be well considered to avoid inefficiency. Table shows only generic categories of techniques.

4.3 Soil, Sediment and Ground Water Sample Collection Tools

For the sampling of soil material different types of drills can be used depending on the soil type and level of contaminating substances. Some widely used types of drills are described below:

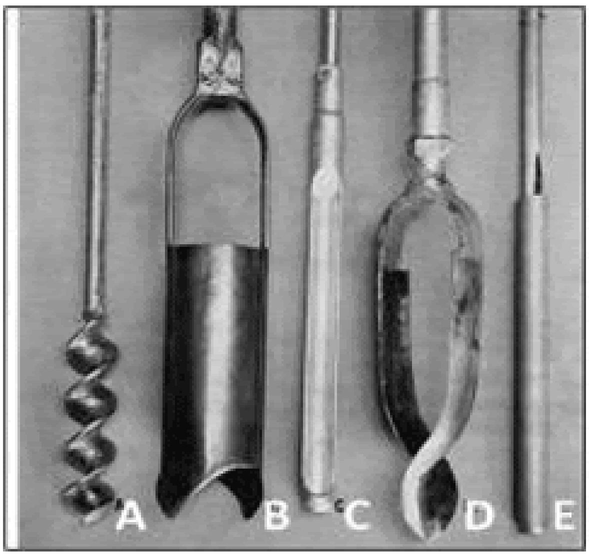
- Hand held techniques
  - Scoops, spoons, and shovels
  - Augers (including split auger)
  - Tube
  - Gouge
  - Thin-walled core samplers
- Power driven drill techniques
  - Screw drilling system: hollow auger drill
  - Screw drilling system: auger drill
  - Displacement drilling system
  - Cased auger/pulse drill

(a) Manual techniques for soil sampling

Hand-held scoops (for 10 to 100g capacity), spoons (typically for 300gm to 2kg capacity), and shovels are used for exploratory holes, test pits and sampling near surface soils. Accurate, representative samples can be collected depending on the care and precision demonstrated by the sample team member. Use of a flat, pointed mason trowel to cut a block of the desired soil can be helpful when undisturbed profiles are required. Care should be exercised to avoid use of devices plated with chrome or other materials. Volatiles may be lost during sample collection.

Example of soil sampling with shovel	*Example of trial pit excavated with shovel*
	

- **Augers** are commonly used to collect near surface samples and, in combination with tube samplers, to collect undisturbed samples. Examples of augers: Edelman-drill, "riverside" drill, gravel drill. This auger is used for drilling up boreholes to the groundwater level. It can also be used in cohesive soils. Smearing can be prevented by using an increasingly smaller diameter or by using a (lost) casing. The "riverside" and gravel drill have more disturbed samples than the Edelman-drill, but samples never cover more than 10 to 15 cm in height.

Example of augers with handle	Example of augers
	

Examples of soil sampling with Edelman auger		
		

Example of Ground Penetrating Radar	PID Ionization detector	*XRF X-Ray Fluorescence*
		

***Table 4.1** Preliminary site investigation survey techniques for quick screening of sites: Basic characteristics and typical application*

	Electro-magnetic methods	Geo-electric and Self-Potential methods	Magnetic field measurement	Ground Penetrating Radar (GPR)	Radio-metric measurement	Seismic (sonar)	Penetration test cones	XRF X-Ray Fluorescence	NIR Near IR luminescence	PID Photo- Ionization Detector	Gas detection tubes
Basic characteristics											
Parameter	Electrical soil resistivity	Electrical soil resistivity	Magnetic susceptibility	Dielectric constant	Gamma-Ray radiation	Acoustic impedance	Various	Concentration (heavy metals)	Concentration (heavy metals/ some organic compound)	Concentration of contaminations in the air	Concentration (parameter sensitive reagent)
Unit	Ω/m	Ω/m	Gauss	F/m	Bequerel	ms or kgm2	Various	ppm	ppm	ppm	ppm
Property of investigation	Electro-magnetic induction	Galvanic resistivity	Magnetic field	Reflection/ refraction electro-magnetic field	Radioactive radiation	Reflection/ refraction of sound waves	Various	Wave-lengths of the emitted X-Rays	Near IR luminescence	Ionization of charged molecules	Speed of chemical reaction
Typical field specification											
Range of depth	0 – 25 m	0 – 100 m	0 – 10	0 – 25	0.1 m (in situ) > 0.1 m (samples)	1 – 100 m	0 – 50 m	0.1 m (in situ) > 0.1 m (samples)	0.1 m (in situ) > 0.1 m (samples)	NA > 0.1 m (samples)	NA > 0.1 m (samples)
Soil/ water/air/ sediment	Soil/ sediment	Soil	Soil/ sediment	Soil	Soil/ water/ air/ sediment	Soil/ sediment	Soil/ sediment	Soil/ water/ air/ sediment	Soil/ sediment	Air (sample)	Air (sample)
Resolution	1 – 25 m	1 – 100 m	1 – 5 m	0.5 – 2.5m	0.1 m	0.5 – 5m	0.1 m	0.1 m	0.1 m	1 m	1 m
Point/line/3D	point	point	point	line	Point	line/3D	line (vertical)	point	point	point	point
Survey type (Survey technique is (+) highly suitable; (0) suitable with restrictions; (-) not suitable)											
Stratigraphy	+	+	0	+	0	+	+	-	-	-	-
Contamination	+	+	0	0	+	-	+	+	+	+	+
Objects	0	-	+	+	-	0	0	-	-	-	-
Ground-water level	0	0	-	+	-	+	+	-	-	-	-

	Electro-magnetic methods	Geo-electric and Self-Potential methods	Magnetic field measurement	Ground Penetrating Radar (GPR)	Radio-metric measurement	Seismic (sonar)	Penetration test cones	XRF X-Ray Fluorescence	NIR Near IR luminescence	PID Photo- Ionization Detector	Gas detection tubes
Practical aspects											
Field personnel (# of field operators)											
	1-2	1-2	1	1	1	>2	1	1	1	1	1
Investigation time needed ((+) quick survey technique; (0) moderate time consuming technique; (-) time consuming survey technique)											
	+	0	+	+	+	-	0	+	0	+	+
Costs (Survey technique is (+) expensive; (0) moderately expensive; (-) low cost)											
	+	0	+	+	+	-	0	+	+	+	+
Much used (Survey technique is (+) used on daily basis; (0) now and then used; (-) seldom used)											
	+	+	0	+	+	-	+	+	-	+	+
Typical type of field survey	Ground-water plume and source recon-naissance / delineation	Groundwater plume and source recon-naissance / delineation	Source and object (drums) recon-naissance / delineation	Stratigraphy, source and object recon-naissance / de-lineation	Source recon-naissance / delineation	Stratigraphy	Stratigraphy and plume Recon-naissance / de-lineation	Source recon-naissance / de-lineation	Source and pathway recon-naissance / de-lineation	Source and pathway recon-naissance / delineation	Source and pathway recon-naissance / de-lineation

- **Tube sampler -** drills are used in (relatively) cohesive soils to obtain almost undisturbed samples. They provide fast and simple information on the (shallow) soil structure. Samples have a small volume but are useful for profile descriptions. The maximum reach depth is between 5 and 10 m below ground surface level. Like augers, tubes can utilize a variety of tips depending on soil type. Tubes are considered better than augers for sampling VOCs. Tubes are similar to augers except that a tube with a cutting tip is attached to the drill rod. Instead of being rotated, the tube is pushed into the soil. Often augers are used to drill the hole and tubes are used to collect the sample. Tubes are not suitable for rocky, dry, loose, or granular material or very wet soil. A variety of tube samplers are available. Some tubes can be driven into the soil by a demolition hammer. This system is often used when debris in the subsurface occurs. There are also fully closed tubes/gouges with liner or with a foil in which the sample is entered.

Example of soil sampling with tube	Example of soil sampling using gouge
	

- **Gouge** - similar to tubes, gouge drills are used to collect undisturbed samples, generally from soft and wet soils. Gouges are long, semi cylindrical chambers made of tapered stainless steel that are pushed into the soil, twisted and recovered to display a full profile of the soil. Gouges are usually used to collect small samples, e.g. to determine soil water content by mass.

- **Thin-walled core samplers** - are most commonly used for collection of undisturbed core samples in cohesive soils, silt, and sand above the water table. Sample collection procedures are similar to split-spoon sampling except that the tube is pushed into the soil, using the weight of the drill rig, rather than driven like Shelby-tube or Continuous-tube.

Typical drop hammer core samplers	Sampling with thin-walled core samplers
 	

- **Drill-techniques for soil sampling**

A metal detector may be used to detect the presence of hidden objects of metallic origin below the surface, such as tanks, barrels and cables. In case such objects are expected at a site it should be considered to excavate a hole by hand before performing mechanical drilling.

Hollow stem auger drill consists of a hollow central shaft with a removable sheet or valve structure at the bottom end. There are two types of hollow auger drills, in simple system the soil is sampled without disturbing operation, and in the more complex system a non-rotating sampling tube is pressed down and collects the sample in the hollow central part, while the surrounding soil is being drilled up through the space surrounding the central part.

Hollow auger drill	Machine driven auger drill
	 

Auger drill can be drilled up to 30 m below ground surface level above the water table in cohesive soils. The jacked ground is mixed, which increases with depth. *Indicative sampling or profile description is only possible when the drill is screwed into the soil like a corkscrew (lowering speed is equal to the rate of the windings) and then not turned when it is pulled up.*

Displacement drilling system is based on the principle of borehole drilling without soil excavation with compaction of borehole walls using special displacement tool. There are two ways to take water samples with this method. In first method relatively thin tube provided at a last point that is pressed into the soil to the desired depth, inside this tube a very thin monitoring well is lowered, then casing is pulled up after which the filter remains. Second method is a sounding tube with an integrated filter that is pressed down until the desired depth is reached, then groundwater samples are taken immediately.

Examples of Power Driven Displacement Drilling System	
	

Cased auger drill is used to drill to the wet sand layer. In case of contaminated soil, casing can be inserted through rotation to limit smearing when it is pulled up. Sample may be taken within or below the casing. In cased auger method, there is a minimum of smearing and wells with a large diameter are constructed. In case of rock or paving, special drill bit has to be used to cut material, such as: drilling of bore holes.

Examples of Auger Drill		
Manual auger drilling	Machine auger drilling	Cased auger drilling
		
Examples of Cased Auger Drill required for Hard ground and rock drilling		
		

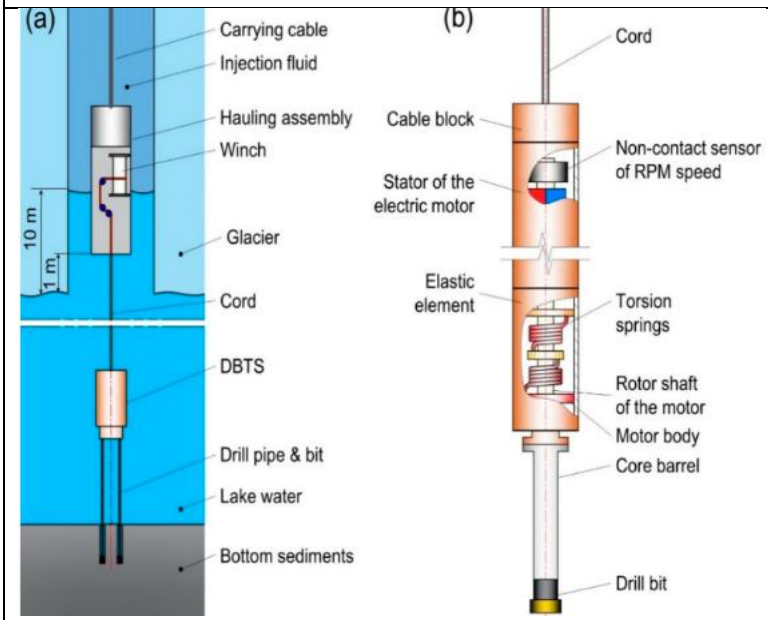
(b) Sediment sampling collection tools

For the sampling of sediment material different types of drills can be used. Some widely used types of drills are described below:

- Piston drill
- Sediment core-sampler
- Grabbers

Piston drill consists of drilling a through tube, normally made of stainless steel, to which extension rods can be attached. The insert tube is pressed into the sediment with the rod system, while the piston is kept at a constant depth with respect to the sediment. This piston maintains a negative pressure, causing the sample over the full cutting depth to be recorded into the penetration tube. The maximum cutting depth of the piston sampler is 2 m. There is no visual inspection if the sample also includes the upper surface. Coarse sand or very watery material drops during the acceleration of the piston bore. There is no provision, other than the vacuum of the piston, to keep it down in the tube.

Sediment core sampler (Beaker type) consists of a cutting head with an attached transparent penetration tube of polyvinyl chloride. Sampler presses or hammers the extension rods into the soil. A piston down tube creates a vacuum, which enables sampling of the best stretch length along with tube (sample tube). Once the penetration tube arrives at the correct depth, a rubber bellow can be inflated in the cutting head so that the bottom of the sample tube can be closed. The sampling unit can then be retrieved. In stagnant water it can be applied to 10 m depth.

<table>
<tr><th>Transparent material piston drill</th><th>Sediment core sampler</th></tr>
<tr><td>


</td><td>

</td></tr>
</table>

Grabbers –Van-Veen grabber is a typical grabber with a cable or rope lowered to the bottom. When hitting the bottom of the suspension cable an unlocking mechanism is set into motion. By subsequently pulling up the cable the sample is snapped out of the sediment. The device collapses weak sludge, and collects, depending on the size, only a shallow sample. It can be applied in non or hardly flowing water to all depths.

Examples of grabbers

Sediment level measuring device: A method to roughly assess the thickness of a sediment layer is to use a hand held tool, as given below:

Example of tool to detect sediment level

(c) Groundwater sampling collection tools

Groundwater samples can be collected using several types of pumps depending on the groundwater depth, sampling of volatile compounds, etc. The following are widely used types of pumps:

i. Suction lift pump
ii. Pressure pump
iii. Bailer sampler
iv. Ball valve pump

Suction lift pump – these are peristaltic pumps, frequently used for shallow ground water sampling. Suction lift pumps apply a vacuum to either the well casing or to tubing that runs from the pump to the desired sampling depth. Most are easily controlled to provide continuous and variable flow rate. Peristaltic pumps utilize a self-priming or power operated vacuum pump. This pump can be used to a maximum groundwater level of 9.5 m below ground level (bgl). It can be used for the sampling of groundwater for testing of volatile compounds, provided the suction height is not over 6 m. For each sample a disposable filter should be used. Filtering the water before bringing it into the sampling bottle is required.

Suction lift pump	Submersible Pump	Bailer sampler
		

Pressure pump - This pump is also known as submersible centrifugal pump, is used for well purging and ground water sample collection. This pump is universally applicable for sampling for chemical testing of volatile compounds, provided the speed of the pump is variable to sampling rate. Submersible centrifugal pumps use an electrically-driven rotating impeller that accelerates inside the pump body, building up pressure and forcing the sample up the discharge line. Commonly constructed of stainless steel, teflon, rubber, and brass, most can also provide a continuous and variable flow rate. Small diameter submersible centrifugal pumps are available that can be used in 2-inch diameter wells and can be operated at both high flow rates for purging and low flow rates for sampling. These pumps can be used for sampling up to 70 m below ground surface level. The risk of contamination is very large; so much attention should be paid to the materials and the cleaning of the pump.

Bailer sampler - Bailer samplers are the most widely used sampling method, due to their low cost. However, other devices like bladder, helical-rotor, and gear pumps generally provide better results when sensitive constituents such as VOCs are present. A bailer is a hollow tube with a check valve at the base (open bailer) or a double valve (point source bailer). The bailer is attached to a line (generally either a polypropylene or nylon rope, or stainless steel or Teflon coated wire) and lowered into the water. The bailer is pulled up when the desired depth is reached, with the weight of the water closing the check valve. Open bailers provide an integrated sample of the water column. Point source bailers use: (1) balls or (2) valves (operated by cables from the surface) to prevent additional water from entering the bailer so that a sample can be collected at a specific point. Maximum depth for sampling is about 70 m below ground surface level.

Ball valve pump - The ball valve pump is used to push water upward. The pump is connected to the end of a sampling hose or tube. By moving the tube and pump down, the ball is moving up and it will let water enter into the tube. By pushing the tube and pump up, the ball is closing, so the water goes up with the tube and pump. The moving can be done by hand or by a machine. The ball valve pump is available in different diameters for different tube sizes. The pump is small, relatively cheap and it can be used to clean a monitoring well by pumping water and sediment after placement, as well as for sampling monitoring wells.

Filtering of groundwater samples

Filtering of sample to reduce turbidity in sample is necessary for testing of a groundwater sample for heavy metals. The sampled groundwater needs to be filtered through a 0.45 µm filter to remove the sediment that causes the turbidity. In line filter can be placed at the end of the discharge of pump. The materials that have contact with the sample should be made from physically and chemically inert material. For every well a new filter must be used.

(d) Construction of Monitoring Wells

For groundwater sampling, existing groundwater wells (well/bore-well/hand-pump) can be used; however, sometimes it is not clear how the installations have been designed, and which stratum the groundwater is derived from. Hence to obtain accurate information for a specific level of contaminants, new dedicated monitoring wells should be installed. Monitoring well is also known as Piezometer that may be constructed for short term or long term depending on monitoring requirement. These wells may be installed at different depths to determine the vertical profile of contamination. Monitoring wells have typically less in diameter up to 5cm and are typically screened less than 5 feet (1.5m). These wells can be used for both measuring level and sampling of groundwater.

These wells can be constructed by drilling bore-holes and using pipes, which are normally made of inert plastic material that does not influence the quality of the groundwater. The pipes have slits through which the groundwater can flow into the pipe where it is extracted for sampling. After installing the pipe, a cap with lock should be applied to be able to prevent disturbance of the wells.

Monitoring Wells

Particular method of constructing monitoring well depends on the purpose of the well, the quantity of water required, depth to groundwater, geologic conditions, and other factors. The optimum length for a specific well is based on aquifer thickness, available drawdown, stratification within the aquifer, and if the aquifer is unconfined or confined.

(A) Key principles of constructing monitoring well are;

- The purpose of monitoring well;
- Evaluate site-specific hydrogeological information from all available sources, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.
- Develop a conceptual hydrogeological model of the site.
- Determine screened interval.
- Select method of monitoring well installation.
- Determine the diameter of the well.

(B) Construction, specifications and precautions:

(i) Properly decontaminate well construction materials prior to installation

(ii) Prevent contamination when joining casings and attaching the screen.

(iii) For long-term monitoring wells, place the filter pack into the annulus to a minimum of two feet above the top of the screen and one foot beneath the well end cap.

(iv) Use bottom caps or end plugs

(v) Use permanent or temporary surface casing if contamination or sloughing is a potential issue (drill augers should never be removed from the hole without concurrently filling borehole voids with appropriate sealant media).

(vi) For long-term monitoring wells, reduce the required filter pack height to allow for annular space sealant. Accurately assess depth of filter pack and apply grout or bentonite chips to seal the annular space.

(vii) If the borehole or monitoring well is advanced through an aquitard, the penetration through the aquitard must be sealed at the same interval using grout or bentonite chips.

(viii) Pour grouts or slurries freely with or without the use of a termite pipe.

(ix) Take appropriate precautions during drilling to avoid introducing contaminants into the well. Prevent vertical movement of water or contaminants between water bearing zones in either the boring or the well annulus.

(x) Avoid using drilling mud, synthetic drilling fluids, or petroleum- or metal-based pipe joint compounds and other potential contaminants unless necessary.

(xi) If it is necessary to add water during drilling, use only clean or potable water and identify the water source.

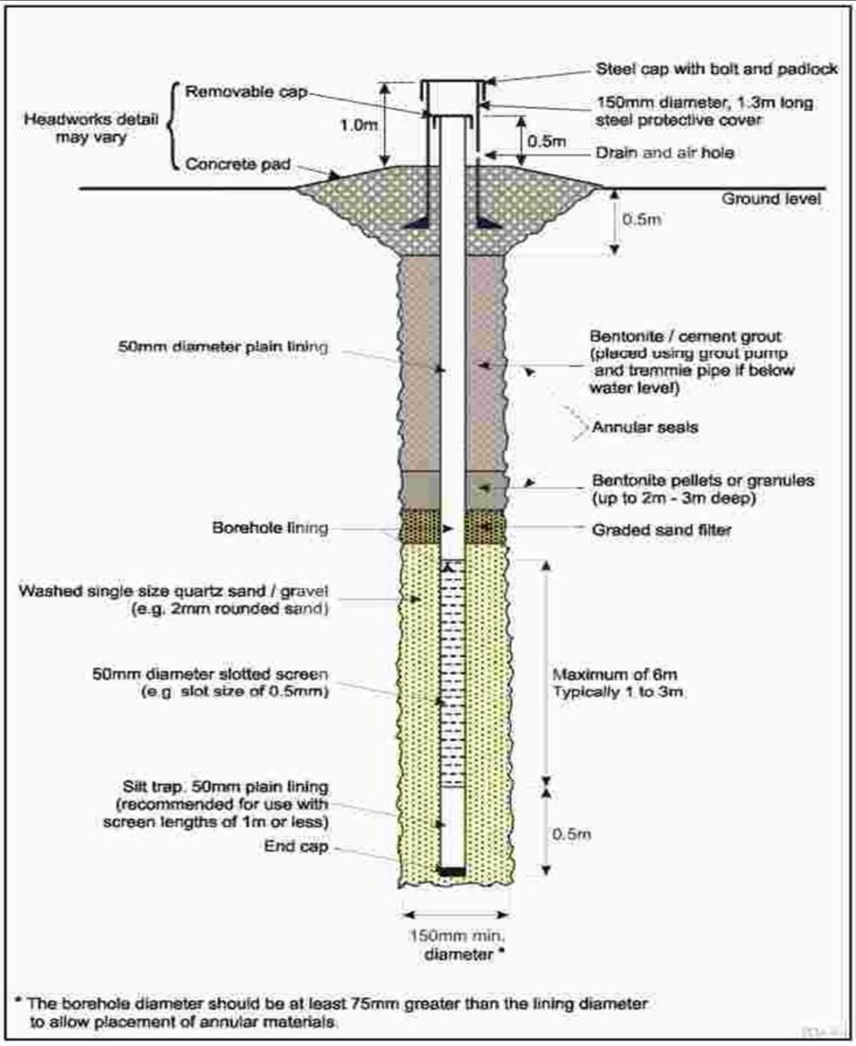
(xii) Add drilling mud to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.

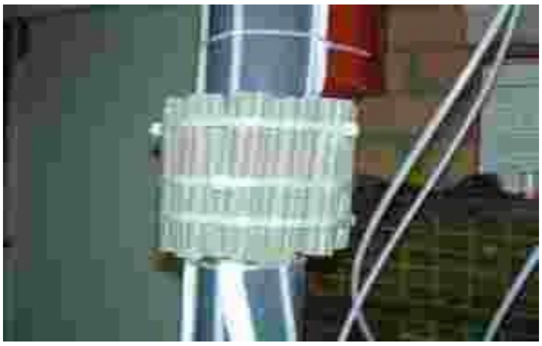
(xiii) Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.

(xiv) Dispose contaminated cuttings in any SLF in consultation with SPCBs/PCCs.

(xv) Complete an “as built” drawing/schematic for each constructed monitoring well.

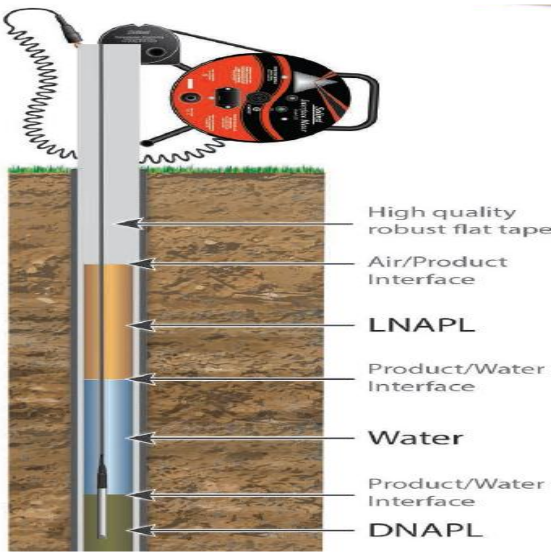
(xvi) Install a cement surface seal, where appropriate.

Example of generic groundwater well design


Bentonite pellets	Bentonite plug
	

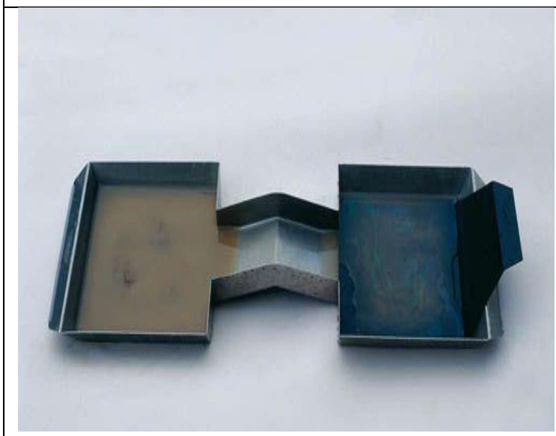
(e) Groundwater level measuring device

Many tools are available to detect the groundwater level in a monitoring well. Groundwater level measurement is commonly measured by a submersible pressure transmitter. These hydrostatic level transmitters are small in diameter and directly suspended by a cable into the well, borehole, deep bore well or monitoring well. One such measuring device is illustrated in figures below.

Examples of groundwater level measuring tools	
	 

(f) Oil water observation tool

Oil detection pan can be used to rapid on-site analysis of soil and groundwater for detecting floating contaminants like oil derivate such as tar, lubricating oil, kerosene and petrol. This tool however does not provide information on the exact substances and concentrations.

Oil-water detection pan	
	

(g) Samples preservation

Laboratories provide information about maximum holding time for samples before analysis of soil or water is carried out. Samples of contaminated material should, as much as possible, be kept under conditions which will not influence the contaminants before arriving at the testing laboratory. Preservation often involves cooling, especially when samples are to be tested for volatile compounds.

Sample cooling methods	
	Cooling gel packs 

4.2 Outcome

The output of sampling tools and techniques for site investigation help in use of appropriate tools for field assessment and sampling required for both preliminary and detailed site investigation studies.

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National Program for Rehabilitation of Polluted Sites in India

Guidance document for assessment and remediation of contaminated sites in India

1st Edition, December 2015




Ministry of Environment, Forest and Climate Change
Government of India

Overview Guidance document for assessment and remediation of contaminated sites in India

Overview Guidance document for assessment and remediation of contaminated sites in India

1st edition, December 2015

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National Program for Rehabilitation of Polluted Sites in India

Guidance document for assessment and remediation of contaminated sites in India

Volume I - Methodologies and Guidance

1st Edition, December 2015




Ministry of Environment, Forest and Climate Change
Government of India

Volume I

0 Introduction

0 Introduction

0.1 Objectives and scope of this Guidance document

Key objective
The key objective of this Guidance document is to provide different agencies, both Government and non-government, involved in the assessment and remediation of contaminated sites in India with methodologies. These methodologies mainly cover [i] the process for selecting and implementing preferred remediation options and [ii] the technical guidelines and standards that can be applied.
The Guidance document has been developed so that the agencies involved in the assessment, investigation and remediation of contaminated sites on a day to day basis will find it to be a practical manual for years to come.

Scope

This Guidance document is arranged in three Volumes as follows:
- Volume I: Methodologies and Guidance;
- Volume II: Standards and Checklists;
- Volume III: Tools and Manuals.

Volume I guides the user through every step of the assessment and remediation process by providing relevant information, flowcharts, practical guidance and considerations. For standards and checklists the user is referred to Volume II, and for more detailed technical manuals to Volume III. The Guidance document is designed as a standalone reference manual and can therefore be considered to either include or refer to all information relevant for dealing effectively with contaminated sites.

It should be noted that the contaminated site remediation industry in Europe, USA and similar countries has accumulated its knowledge and experience over a period of more than 35 years. It is therefore not intended to capture all that in this Guidance document. By contrast, the Guidance document aims to provide a judicious mix of general overviews and detailed specifications to encapsulate the global practical knowledge and theoretical basis, international industry practices and above all, the great wealth of practical experience around the world for an experienced and trained technical manager in India to take up the next steps of the National Program for Remediation of Polluted Sites (NPRPS).

The document was developed while keeping in mind factors such as [i] the nascent phase the site remediation industry in India is in, [ii] the wide ranging variety and complexity of individual sites and their particular characteristics, [iii] the capacity gaps at different levels, and [iv] the particular interrelation between technical and non technical (legislative, legal, financial) factors typical for India.

Content
The Guidance document covers the entire gamut of technical aspects stakeholders need to address while dealing with a contaminated site in India. Each aspect is dealt with the appropriate degree of general descriptions and specific details. The document presents the complete process of dealing with a contaminated site, from identification through assessment and remediation to delisting, in a sequence of fourteen steps, explains their interrelations, and provides detailed presentation of each of the steps. While the focus is on practical, technical, aspects, wherever relevant reference is made to institutional, legal and financial aspects.

Targeted users: technical and non-technical
The aim of the Guidance document is to provide practical guidance to various types of users by providing references to technical issues they face on a day to day basis. While all professionally involved stakeholders may find the information useful, the Guidance document is mainly aimed at the competent authorities and/or agencies assigned to implement any part of site remediation works.

The Guidance document can be used by a non-industry professional, policymaker or manager, or as a technical manual by those more directly involved in site remediation in India. While the general reader does not need to know anything about site remediation, a degree of familiarity with basic remediation issues is expected from the technical user wishing to explore the details.

The level and complexity of technical details included assumes that the user is trained as an engineer or manager, is dealing with contaminated sites on a day to day basis, and has a background in the fields of one or more of: [i] civil engineering, [ii] chemical engineering, [iii] geology, [iv] hydrology or [v] environmental (waste) management. However, the document is set up in such a way that it is also useful for decision makers and those persons supporting the engineers.

For providing technical guidance and supervision
With the help of the Guidance document a trained engineer should be able to give technical direction to the approach of the assessment and the remediation of a contaminated site. The document will guide such a reader through every step of the assessment and remediation process by providing, among other information, flowcharts, data, checklists, and considerations. Detailed information is included, e.g. in the form of data overviews, checklists and technical manuals. For additional detailed information, e.g. on methods, equipment and models, the Guidance document refers to websites and other documents.

For dealing with contamination, not its prevention
Experience in many countries has led to international consensus that dealing with existing contamination on a site is very different from preventing such contamination in the first place. It is well accepted that the key in prevention is a thorough environmental awareness. For example, at sites where potentially contaminating activities take place, technical measures to prevent hazardous substances from penetrating into soil, groundwater or surface water are necessary. One of the better known of these measures is providing the site with an impermeable floor.

This Guidance document primarily deals with issues concerning assessment and remediation of already contaminated sites. Any technical measures for the protection of soil, groundwater and surface water or for the prevention of further contamination are covered only in passing, where appropriate.

For training and technical capacity building
An equally important intended use of the Guidance document is for initial training and technical capacity building among various stakeholders and agencies involved in the Indian site decontamination industry. While it is impractical to capture in one document many hundreds of man years of global site decontamination experience, the emphasis in the Guidance document is on providing practical knowledge and, quite literally, guidance, to a person involved in the Indian site decontamination Industry.

A non-technical person, for example a policy decision maker, a finance professional or a project manager, may use relevant sections of this document to familiarise him- or herself with the process of identification, assessment and remediation of contaminated sites and how it affects the non-technical decision parameters.

For a technical professional involved in a specific aspect of carrying out, supervising or regulating site decontamination, both organised overviews, adequately contextualised, and sufficient details on those aspects are provided. It is intended that after digesting the specific information provided in the Guidance document, the technical professional may seek further details in the wide ranging references the Guidance document provides.

Terms and definitions – the Glossary
For terms and definitions please refer to the Glossary, presented at the end of Volume I.

0.2 Introduction to contaminated sites

Generally, around the world, it is an accepted practice to describe contaminated sites as areas in which toxic and hazardous substances exist at levels and in conditions which pose existing or imminent threats to human health or the near and surrounding environment (see Glossary for the formal definition of a contaminated site).

Such sites often pose multi-faceted health and environmental problems to society. They can adversely impact any or all parts of the surrounding environment, particularly surface waters, soils, and groundwater and can result in people being knowingly or unknowingly exposed to toxic substances. Contaminated sites may include production areas, landfills, dumps, waste storage and treatment sites, mine tailings sites, spill sites, chemical waste handler and storage sites. These sites may be located in residential, commercial, agricultural, recreational, industrial, rural, urban, or wilderness areas. This situation is also applicable in India. This document is aimed at dealing with a broad range of types of contaminated sites occurring in India.

However under NPRPS bio-medical wastes, mining wastes and radioactive wastes have not been considered as these are dealt separately under the relevant Acts and the rules made thereunder. Various elements of the process and content of assessment and remediation, as described in this Guidance Document, can be used for remediation of other types of waste as well.

While it is recognised that legal aspects of the origin of a contaminated site may or may not be clear, the technical issues concerning disposal or dumping remain the same for legal or illegal contamination.

More specifically, the types of sites addressed in this Guidance document are:

- "Point" sites, such as dumps of waste or individual contaminated facilities (an example is shown in figure I-0.1 below);
- "Area" sites, a site within a broader area of ongoing and legacy contamination where the site of concern needs to be addressed in this wider context. An example of this is an individual dump within an industrial area, where there are also other sources of pollution (an example is shown in figure I-0.2 below);
- Municipal dumps, often with an unclear history, which may contain hazardous substances dumped before the municipality gained effective control (an example is shown in figure I-0.3 below);
- Brownfields, which may, or may not, have clear ownership and which have development potential if the contamination problems can be successfully resolved.

Figure I-0.1 Waste material at Ranipet site, typical "point" site

Figure I-0.2 Contaminated land near Eloor, typical "area" site

Waste versus soil contamination
A by product of almost every human activity anywhere is waste, which can manifest itself in countless different forms. Not all waste automatically leads to soil contamination. In fact, when waste is effectively reused, it can actually avert soil contamination. Waste does lead to soil contamination when it negatively affects soil or groundwater or other environmental features. Most often, this is due to uncontrolled dumping or lack of timely suitable remediation measures.

The soil comprises three phases
“Soil” is one of the most universally used every day terms in all societies and often means the same to all users, except maybe in very specific contexts. In this document, soil is considered to comprise three phases, including the organisms living in these phases:

- Solid phase, consisting of the sand, loam, and clay particles, but also including the organic solid elements, like decomposing leaves;
- Liquid phase, consisting of the groundwater;
- Gaseous phase, consisting of the air trapped among the soil particles.

Underwater soil is usually referred to as ‘sediment’, and also comprises three phases, albeit that the gaseous phase is very small.

Soil contamination can occur in any of these three phases or in any combination thereof. Contamination of the solid phase may be visible, e.g. when hazardous waste has been dumped on top of the soil, or not visible, e.g. when dumped waste was covered. However, contamination of the liquid and gaseous phase is often not clearly visible, and almost always entails specific, sometimes far greater, risks. This is because local soil contamination often spreads relatively easily, thereby contaminating ever larger volumes of soil, groundwater or air.

Figure I-0.3 Municipal Waste dump site of Dhapa

0.3 General description of contaminated sites in India

At the time of writing this edition of the Guidance document the availability of formal data on contaminated sites in India was still relatively limited. An analysis of available data at the time showed that in the sites already formally identified, only a relatively small number of contaminants were present, i.e. mainly heavy metals, pesticides and fluoride. However, it is felt by experts and generally agreed in India that when a comprehensive inventory of contaminated sites is carried out over longer periods of time, the extent of the contaminated sites, the range of contaminants and types of sites can increase substantially. This is the conclusion when considering the size of the country, the extent and diversity of its economy and industry, the industrial and non-industrial processes adopted (which are usually comparable to international processes) and the current practices of handling contamination in different sectors.

Keeping this in mind and taking cues from global practices, a system has been developed for the generic classification of types of contaminated sites in India. All sites identified in India at the time of writing this document could be assigned to a type within this classification system, except in cases where contamination is limited to surface water.

Contaminated site classification system
The proposed classification system distinguishes the following main types of contaminated sites:

- Source related:
    - Type S1: Land bound solid phase contamination
    - Type S2: Water bound sediments solid phase contamination
    - Type L: Land bound liquid phase contamination
- Pathway related:
    - Type P1: NAPL contaminants in soil (Non Aqueous Phase Liquids)
    - Type P2: Groundwater contaminations

Depending on the specific situation, a site may fit into more than one of these types. Subtypes are defined where necessary to enable the system to absorb additional specific site characteristics.

This system is, in our view, fully suitable to typify and classify the large number of contaminated sites that may be added to the current inventory in future. The complete classification system is outlined in the explanation of the typology in the Glossary.

0.4 Introduction to the concept of Risks and Intervention

When contaminated sites require intervention: the concept of risks
Contaminated sites can cause risks to human health and to the environment. The extent of risk and the impact of contamination depends on many factors, but key is the probability of contact between the contamination and the surroundings. In case there is no contact between the contamination and humans or the environment the

contamination carries no risk. This is, in all its simplicity, a conceptually important point to keep in mind.

International experience shows that not all soil contamination requires intervention. In the Netherlands, for example, the soil decontamination industry has evolved over the last 35 years and the expertise developed indicates that an optimum exists between the two extremes of decontaminating all contamination at all sites, so as to eliminate all potential risks, or decontaminating only to a certain acceptable level of risk at selected sites. Such an optimum is specific to a country or region and is influenced by many factors, such as the site inventory, characteristics of sites, geography, hydrology, as well as social, cultural, financial and political factors. For India too such an optimum needs to be found. This will involve taking into account considerations specific for India. Experience from other countries is a useful guide in reaching such an optimum balance.

The perception of a “risk” associated with an event or situation depends on a multitude of complex factors. Among these are the context, the observer, environmental factors, time factors, the historical record, the human factor. In view of this, the international site remediation efforts over the years have developed tools and approaches for quantitative assessment of risks associated with a particular contaminated site. These tools and approaches are applicable in India and it is recommended they should be applied.

Risk assessment: the Source-Pathway-Receptor approach
In this context, it is internationally agreed that it is vital to determine the chance that either humans or the environment will get in contact with the contamination. The widely accepted approach for this risk assessment is the ‘Source – Pathway – Receptor’ (SPR) approach. Within this approach, the source is the contamination, e.g. a leaking oil tank or a layer of pure oil in the topsoil. The pathway is the route between the source and the receptor, and the receptor is a human, animal, plant, ecosystem, property or a controlled water that may be affected by the contamination. An example of the three is shown in figure I-0.4 below. The generally accepted principle is that adverse effects of contamination are only considered to occur when contamination actually threatens humans or resources, i.e. puts them at some substantial risk. This happens only when all of the three elements (source, pathway and receptor) are present.

Figure I-0.4 Source - Pathway - Receptor

Risk from contamination?
An amount of waste is stored on an industrial site (source). Water containing hazardous elements leaches into the soil and into the groundwater, which takes it further downstream (pathway). The contaminated groundwater reaches a well that is used for drinking water by the local community (receptor) *→ YES, in this situation there is a risk that the contamination causes adverse effects on human health.* Assessment should be aimed at establishing whether that risk may be substantial, in which case there may be a need for intervention.

In the situation described above the waste is stored in an enclosed space and the water that leaches out is captured and removed in a controlled way to be treated elsewhere (there is no pathway, so the hazardous elements cannot reach any receptor *→ NO, in this situation there is no substantial risk that the contamination causes adverse effects on human health.*

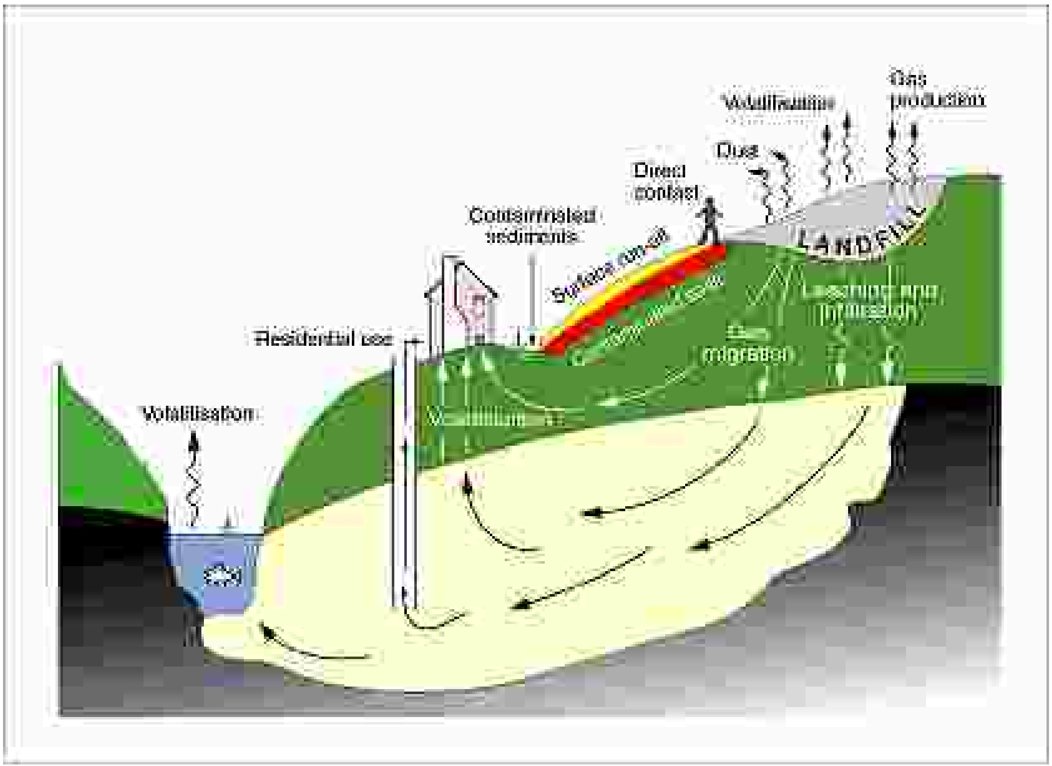
At any given site the exact situation with respect to each of these three elements and their interconnectivities determine [i] the need to intervene, [ii] the points of intervention (start and end), as well as [iii] the focus and the potential types of remediation options. Site assessment should show whether contamination puts human health or the environment at substantial risk. Only in case these risks are deemed unacceptable by the prevailing law or by the stakeholders the need for intervention arises. Only then a process of selection of intervention (remediation) measures needs to be initiated, eventually leading to remediation action.

In various risk assessment methodologies, the contamination (source) is clearly identified, as well as what that source may affect (receptor) and through what route the source may reach the receptor (pathway). It is important to note that receptors may be located on-site as well as off-site, and also that while in a current situation there may be no pathway, this can still develop over time (sometimes long periods), by diffusion through groundwater, surface water, sediment or air.

Most of the available risk assessment methodologies use a tiered approach, which starts with a relatively quick qualitative assessment. If needed this may be followed by a more elaborate semi-quantitative assessment, based on model calculations, and, again if needed, a comprehensive quantitative assessment. A quantitative approach involves actual measurements in contact media, such as indoor air, vegetables or drinking water.

Information for risk assessment: the Conceptual Site Model
No matter what approach is used, input of site data will be needed. Conceptual Site Models (CSM) are commonly used to implement a structured and efficient investigation for risk assessment. Such a model is developed by integrating as much relevant information on the contaminant situation as possible. This helps to understand the mechanics at the site, and may result in an image like the one in Figure I.0.5 below. Volume III-2.2-i presents guidance on how to develop a CSM and its role in the assessment and remediation of sites.

Figure I.0.5 Conceptual model of landfill exposure sources and environmental pathways



Source: Petts, J. and G. Edulgee. Environmental Impact Assessment for Waste Treatment and Disposal Facilities, p. 229. John Wiley and Sons, Chichester, 1994

Socio-economic issues

In addition to the adverse effects to human health and the environment, a contaminated site and its remediation process can cause lesser or greater social and economic disturbance in local and regional surroundings. International experience gives some pointers, which are also applicable to India.

Pollution during remediation

During remediation works, impacts of air and noise pollution on the local communities depend on the duration of the project activities. For example, if the transportation distance for waste from the site to say a landfill site is short the air pollution impact will be less. Higher air pollution impact can be anticipated if a lot of loading and unloading is required for site development. Noise pollution may be due to excavation activity, loading and unloading of waste, transport vehicle movement. Spillage of wastes during transportation may cause negative impacts on the community. However, if proper measures to stabilise the waste are taken this impact will get reduced.

Potential accidents

Transportation by road may cause accidents. This risk increases with increasing transportation frequency and distance.

Land value
Research has found that the public perception of the value of contaminated land is often not in line with reality. The general public usually perceives contaminated land to have hardly any value. In many cases, this perception has created a significant obstacle for redevelopment plans involving contaminated sites. In reality, when redevelopment and remediation plans are integrated from the start, costs for remediation often turn out to be much lower than the value of the land, even prior to remediation. Communication and awareness building may help to reverse this perception.

Business activity, income and employment
Remediating a site may have both positive and negative effects on income and employment of individuals or a group. The larger the remediation action the more positive the long term impact on employment opportunities is likely to be. Development of a site for storage and disposal of waste also generates employment opportunities. In extreme cases of contamination remediation may induce positive health effects. The reduction of the (unpaid) sick leave days may in turn lead to increased income for the local community.

Remediation action may also negatively impact business activity and endanger the livelihood of the local community or part thereof at and near a contaminated site. As a general rule, the impact of long term remediation action is usually significantly higher than the impact of short term remediation action. An example of negative impact of remediation is a clean capping layer, applied as a remediation measure, that renders impossible existing use of a landfill by the local community. In this situation support for the remediation option is likely to be impacted negatively by of the effect on the existing situation. In such a case a proposed solution should include a livelihood for the affected part of the local community.

Socio-economic impact may be direct, indirect and cumulative, depending on the site and remediation characteristics.

Assessment of the socio-economic issues
In each specific case, these and other potential social-economic issues should be assessed through a formal and structured effort. The aim of this effort should be to determine the level of significance of any given issue and a quantification, as far as possible, of the socio-economic costs and benefits. This process entails [i] identification of the socio-economic issues of the nearby areas, including the type of settlements, and [ii] assessment of the significance of the impact of each issue, either quantified or in qualitative terms like low, medium, or high.

The need for community involvement
It is generally accepted that the community affected by any economic activity, including remediation of a site, has a legitimate right to understand and to be involved in decisions that may affect them. Therefore, close interaction with the affected community, e.g. by public consultation meetings like the one in figure I-0.6 below, is recommended and may also prevent undue concerns about the risks during

remediation or site testing work. Community involvement and consultation is most effective when initiated at an early stage of any remediation project.

Assessment of the impact of socio-economic issues is an integrated part of any site assessment and remediation process. Views of the stakeholders, including the local community, are needed for designing any successful remediation project. The consultation process helps in making the project responsive to social development concerns, and increases the chances of reaching options that enhance benefits for the community while mitigating risk and adverse impacts.

Figure I-0.6 Public Consultation Meeting
(picture by Andra Pradesh Pollution Control Board)

0.5 Guiding principles for decision making

Programme level
A number of guiding principles serve as reference points for international policymakers and programme managers when developing site assessment and remediation programmes. These principles are commonly applied, regardless of geographic, social, cultural and economic contexts. Therefore, these principles can be, with proper review and adaptation to Indian conditions, considered for use as a reference framework for India, at Central as well as State level.

Strategic principles at programme level
Pollution by itself does not usually incite action, it is when risks become apparent that wheels are set in motion. The main guiding principle is always the elimination of or minimizing the risks for human health caused by pollution, with the prevention of risks for the environment following closely. With drinking water being the strategic asset that it is, a guiding principle is the protection of the groundwater quality in aquifers for drinking water storage or with drinking water storage potential.

Typically, the capacity required to assess and remediate the listed sites exceeds the available capacity. In that case, the guiding principle of site prioritisation is applied. A guiding principle of a different nature is the one that states that the notification of sites should be a solid procedure. The reason for this is that notification of a site usually incites stakeholders, including operators, owners, the local community, developers, NGO's and local authorities, to expect that remediation may be implemented in the near future.

Typical strategic principles for a remediation programme
- Elimination of or minimizing the risks to human health and to the environment caused by contaminated sites;
- Protection of groundwater quality in aquifers for drinking water storage or with drinking water storage potential;
- Prioritisation of sites for remediation action, in case the capacity required to assess and remediate the listed sites exceeds the available capacity;
- Development and implementation of a solid procedure for the notification of contaminated sites.

Typical operational principles for a remediation programme
The operational principles for a remediation programme are largely based on the strategic principles. Because the prevention of risks is key, any site assessment and remediation programme will be based on the assessment of risks. The information such assessment yields is needed to establish the risks, to prioritise the sites and to direct remediation action towards the reduction of those risks.

- Assessment of risks and potential risks caused by contaminated sites and by probably contaminated sites;
- Application of the Source-Pathway-Receptor approach, including standard target values for remediation, coupled with risk-based action;
- Implementation of capacity building, e.g. by offering a structure for the systematic acquisition of knowledge and hands on experience;
- Reconnaissance and notification of newly discovered probably contaminated sites.

Individual Site level
Guiding principles are also available for those dealing with an individual contaminated site.

Typical strategic principles for a site specific approach
- Appraisal of remediation objectives, including prevention of further contamination, using generic and site specific criteria (environmental results, technical feasibility/risks, costs, impact of works, available time, spatial planning, social aspects);
- Application of simple, robust and validated site assessment and remediation solutions. Innovative technologies might be considered if these have been successfully applied in well-documented field trials;
- Prioritisation of the reduction of human health risks, as opposed to ecological risks, unless highly valued ecosystems are under threat.

Figure I-0.7 Prevention of actual contaminating activities is important before starting remediation activities

Typical operational principles for a site specific approach

- Whenever possible, application of an integrated approach, i.e. a combination of remediation with reconstruction or redevelopment of the site and/or its surrounding area. In practice, this will usually mean that the remediation design is integrated in the redevelopment plan. In some cases it can be the other way around, when land use planning needs to be adapted to the contamination situation.

> An example of a situation that may call for adapting intended land use to the contamination situation is intended redevelopment of a former dumpsite for toxic waste. Remediation towards a situation that renders the site fit for agricultural or residential use would require high costs, whereas it may be more cost effective to aim the remediation at use of the site as an industrial area.

- Whenever final remediation objectives can be reached in the longer run but not at once, application of a stepwise approach for improvement of the site situation. This under the condition that the most important risks can be brought under control (figure I-0.7) and temporary safety measures are in place where necessary;
- Design and implementation of an iterative sequence of activities for the assessment of contamination and the selection of the most appropriate remediation option. Review of and discussion on intermediate data, results and designs at several stages often leads to the most effective and efficient remediation solutions;
- Focus on assessment activities that provide useful information for the selection of a remediation option and re-use of the site.

0.6 Legal, institutional and financial aspects

At the time of writing of this edition of the Guidance document the key assumption is that the **Ministry of Environment, Forest and Climate Change** will delegate the central management of NPRPS to a central **Remediation of Polluted Sites (RPS) Authority**. In the current plans, outlined in the Task 4 report of Assignment 3 (December 2015), this authority is to be involved in Programme management as well as in Site related programme implementation. This authority is to be supported by the **Central Pollution Control Board (CPCB)**, where the latter will be responsible for the information management, including the management of the polluted site registry and the coordination of the SPCB's. The **State Pollution Control Boards (SPCB's)**, in turn, will provide CPCB with data on the identified polluted sites, each within their own jurisdiction. On state or union territory level the remediation of sites and their reuse is facilitated by the **State or Union Territory Government.**

The performance of site assessment is usually commissioned to an independent third party **site investigator**, while site remediation is usually performed by a third party **remediation contractor**. Post remediation monitoring can be performed by either a site investigator or a remediation contractor. All are likely to engage an independent accredited **laboratory**, either third party or part of CPCB or SPCB, for the analysis and testing of soil, sediment, groundwater and surface water samples, collected during site assessment or remediation.

This Guidance document could serve as a knowledge base for the technical aspects that are important for all stakeholders mentioned above. The legal, institutional and financial aspects are set out in more detail in the Task-4 report of Assignment 3, 'National Program for Remediation of Polluted Sites'.

0.7 Steps in the site assessment and remediation process

In this Guidance document the entire process of intervention in a contaminated site, from its earliest identification to post remediation measures, is described in a sequence of fourteen distinct Steps. This set of Steps covers all activities that are performed in dealing with such a site. Wherever applicable, this Guidance document refers to these fourteen Steps. The same Steps, with identical descriptions, are also used in correlation with the non technical aspects, i.e. legal, financial and institutional, of dealing with polluted sites.

The fourteen Steps are outlined in table I.0.1 below.

Table I.0.1 The fourteen Steps in the site assessment and remediation process

Step	Title	Concise description
Identification		
1	Identification of probably contaminated sites	A structured procedure for the identification of polluted sites, the collection and systematic computerised storage of data serving that purpose.
2	Preliminary investigation	A preliminary site assessment is performed in a desk study and a site inspection, to confirm types of contaminants present. In case the results of the preliminary site assessment warrant this, a preliminary site investigation is performed. This involves investigation to assess if the site may pose threat to human health and environment.
3	Notification of polluted site	Notification of a contaminated site as 'polluted site' to restrict activities pending final remediation, trace liable parties.
4	Priority list addition	The programme managing activities to rank sites based on the threat to human health and environment.
Planning		
5	Remediation investigation	Detailed site assessment, including risk assessment, is commissioned to provide information for inventorying and designing multiple options for rehabilitation. For each option the (post) remediation target and the recommended approach are described. The potential options will be assessed using a set of criteria, and as a result of this assessment the optimum option will be selected.
6	Remediation design, Detailed Project Report	The selected remediation option is designed in greater detail, detailed costing and planning is carried out and responsibilities are analysed in a Detailed Project Report (DPR).
7	DPR approval and funding	The competent authority would approve the DPR. Furthermore, the process of raising funds, maintaining funds and disbursing funds for remediation activities.
Implementation		
8	Implementation of remediation	Preparation, commissioning and implementation of remediation works. Supervision and validation investigation during implementation.
9	Approval of remediation completion	Evaluation of the remediation works and approval of the results by the competent authority.

Step	Title	Concise description
Post remediation		
10	Post Remediation Plan	In case residual contamination remains at the site, post remediation measures are designed to ensure end goals of remediation will be reached. The measures are described in a plan including long term review.
11	Post Remediation Action	The site is monitored periodically to ensure pollution limits are within the values as determined by the end goals of final clean up report and that the land is being used for the purpose as permitted by the end results. If necessary active maintenance measures are taking place.
12	Cost recovery	Any costs, fees and penalty that have not been paid in advance or recovered from responsible person would be recovered either by enforcing financial security or through the recovery process of arrears of land revenue or public demand.
13	Priority list deletion	Upon completion of remediation activities, the site is marked in the database as 'remediated'. If necessary monitoring activities may continue.
14	Site reuse	Reuse of the site after approval of remediation results.

0.8 How to use this Guidance document

Document structure
This Guidance document is organised as a set of documents, arranged in three Volumes:

Volume I	Methodologies and guidance
Volume II	Standards and checklists
Volume III	Tools and manuals

This **Volume I** is the core of the Guidance document set. It presents guidance and instructions as to how to perform each of the fourteen Steps in the site assessment and remediation process. The correlation among the Steps is shown, to enable the user to see what happened before the Step he is involved in and what should happen after completion of that Step. Centred around a concise description of actions to perform the Step the user is involved in, the guidance details aspects for an effective performance, like data needed and where these may be found, and control mechanisms. Wherever relevant, the guidance includes references to Volume II and III and to websites and documents. Volume I is set up in such a way that it may be used in capacity building. It also includes an introduction for aimed at decision makers.

Volume II contains reference data in various forms. Engineers dealing with contaminated sites may use Volume II on a day to day basis to refer to data, standards, criteria and checklists. Every one of these is linked by a reference to one or more descriptions of Steps in Volume I. Therefore this Volume I document should be used in conjunction with the other two Volumes.

Volume III contains more extensive data like technical manuals. Examples of manuals presented in Volume III include a Site Inspection Protocol, points of attention for fieldwork and laboratory testing, an overview of available remediation techniques, and methods for the evaluation of remediation options. Like Volume II, Volume III is intended for day to day reference by engineers dealing with contaminated sites.

Effective use of this document
In Volume I the user will find guidance on the performance of every one of the fourteen Steps in the site assessment and remediation process. The structure of the document seeks to aid the user to quickly familiarise himself with the essence of every Step, after which he may refer to the guidance on the activities to be performed.

Each of the next Chapters presents guidance to a single Step. For quick and easy reference the numbering of the Steps corresponds with the Chapter numbering. For example, Step 5, Remediation investigation, is presented in Section 5. More complex Steps have been subdivided in Tasks, presented in Subsections. For example, Step 5 consists of five Tasks, presented in Subsections 5.1 through 5.5. This means the user may find guidance on the performance of Task 5.3, Setting remediation objectives, in Subsection 5.3, and so on.

The user who wishes to quickly grasp the sequence of steps may refer to the Overview of the Guidance document, on the fold out page at the end of this Volume. Should he wish some more detail on the different steps he may combine this with the introduction to every Step, invariably presented in the first part of every Section. For example: the introduction to Task 5.3 may be found in Subsection 5.3.1, the introduction to Task 5.4 in Subsection 5.4.1, and so on.

The user who wishes to be guided in the performance of a particular Step may refer to the Section describing that Step. Every Section is invariably structured as shown below.

Presentation of description of Steps and Tasks in Volume I of Guidance document

- Section 1: Introduction to and scope of Step
  - Brief summary of the Step;
  - Flowchart showing the position of the step in the process;
  - List of the activities to be performed within the scope of the Step;
  - Brief reference to the parties responsible for performance of the activities.
- Section 2: Guidance for performing the activities of Step
  - Description of the activities to be performed;
  - References to Volume II for standards and checklists, to Volume III for manuals and tools, and to external sources for more detailed information supporting performance of the activities;
- Section 3: Step output
  - brief summary of the output the Step should result in.

For guidance on a particular Task the user may refer to the outline above, while reading ‘Subsection’ for ‘Section’.

Volume I

Step 1 Identification of probably contaminated sites

Step 1: Identification of probably contaminated sites

1.1 Introduction to and scope of Step 1

General description and connection to other Steps
Step 1 concerns the identification of probably contaminated sites as defined in Box I-1.1. In this Step 1 a decision can be made whether or not a site may be regarded as a probably contaminated site requiring further investigation.
This is the first step in the process of assessment and possible remediation of a contaminated site. The figure below shows how this step is connected to the preceding and subsequent steps within the sequence of site assessment and remediation.

Activities
Within this step the following activities are to be performed:
1) The collection of information on probably contaminated sites (for example any existing site investigation reports, regulatory records, petitions, or complaints);
2) The verification and evaluation of the information obtained. This may also require a site visit.

> **Box I-1.1 Definition of a probably contaminated site**
>
> A probably contaminated site is an area (whether or not delineated) where the presence of contaminants is suspected but not conclusively determined or where contaminants exceed specified standards but the threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity is not conclusively established.
> A probably contaminated site may require further investigation to establish whether it is a contaminated site that requires remediation.
> The area may consist of aggregation of contamination sources, the areas between contamination sources, and areas that may contain contaminants due to migration from contamination sources.

Responsible Parties
The activities in this step are typically carried out by technical specialists within the competent authority for the assessment and remediation process. If a specialized agency/consultant is appointed to review the information this should be supervised by the competent authority.

The team involved should demonstrate in-depth knowledge and experience of hazardous waste production associated with industrial processes, and of the environmental fate, transport and degradation characteristics of contaminants (e.g. mobility, biodegradability).

1.2 Guidance for performing the activities of Step 1

This section presents concise guidance for the performance of the activities within Step 1. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Data Collection

Information regarding probably contaminated sites may be derived from reactive or proactive processes.

In a reactive process of Data Collection the competent authority may receive petitions, reports, complaints etc. from local or state level agencies, government agencies, the general public and NGOs. Some examples to illustrate which information may be received:

- Reports on the production, treatment, transport and disposal of hazardous waste, by private parties, including operators and land owners, members of the public or government agencies.
- Petitions or complaints on the suspicion of presence of hazardous materials or substances at a site, by the public or local government agencies. This may include reports on nuisance caused by odour or dust, or visual evidence of the presence of waste material.
- Complaints, through various governmental organisations. These complaints should be forwarded to the competent authority.

Figure I-1.1: coloured tap water, indication of contaminated ground water

The use of a standardised petition format will improve the completeness and quality of the information necessary for submission of a well-founded petition (refer *Example Petition format for identification of probably contaminated sites, Volume II-1-a*).

In a proactive process of Data Collection the data are gathered through a structured process for systematic information collection by the competent authority. This kind of information may be obtained following reviews of:

- hazardous waste registers regarding generation, transport, treatment and disposal of hazardous waste;
- the locations of municipal solid waste dumps;
- records of government agencies that own or control land;
- regional plans and development plans regarding spatial planning;
- industries regarding change of land use.

<u>Activity 2 – Data verification and evaluation</u>

The data obtained during the Data Collection should be verified and evaluated. The initial step is to establish whether the data contains sufficient information to warrant any further investigation of the site or not. The data needed to make this decision is described in the *Checklist relevant data for identification of probably contaminated sites, Volume II-1-b*. In the event there is insufficient data, or data of insufficient quality, to make the decision, then more data should be collected.

Verification of data can be done by collecting information independently from the person or organisation responsible for submitting the original petition, report or complaint. Often, a brief site visit may be beneficial to enable a visual verification of the situation by the reviewing team. Interviewing relevant stakeholders usually yields information that will at the very least provide colouring to the previously collected data. In addition, information by stakeholders will prove useful in the verification of these data. At this stage, interviews can generally be limited to local stakeholders, whom may be interviewed during the site visit.

Stakeholder	Interview objective	Level
Site owner	collect information, verify data	site
Site operator	collect information, verify data	site
Local businesses and residents	collect information, verify data	site and direct vicinity

Figure I-1.2: Site visit

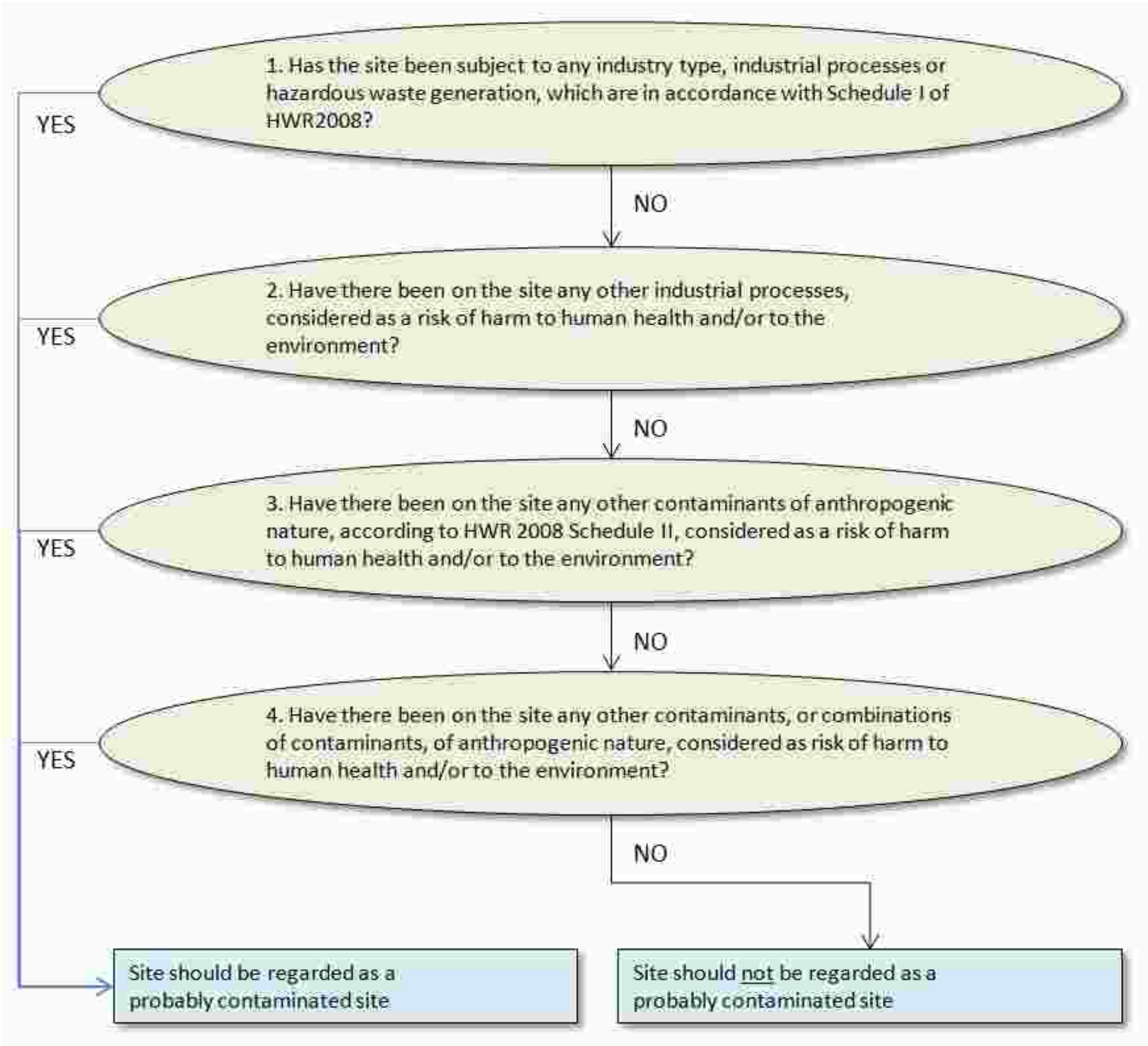
Once the appropriate data has been obtained and verified an evaluation assessment of whether or not the site qualifies as a 'probably contaminated site' may be undertaken. This evaluation comprises answering the following questions:

1. Has the site been subject to any industry type (number 1.12 of *Checklist relevant data for identification of probably contaminated sites, Volume II-1-b*), industrial processes (Checklist, number 2.3) or hazardous waste generation (Checklist, number 2.4), which are in accordance with Schedule I of Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008?
2. Have there been on the site any other industrial processes (Checklist, number 2.3), considered as a risk of harm to human health and/or to the environment?
3. Have there been on the site any other contaminants of anthropogenic nature (Checklist, numbers 2.2 and 2.6), according to Schedule II of Hazardous Waste Rules 2008, considered as a risk of harm to human health and/or to the environment?
4. Have there been on the site any other contaminants, or combinations of contaminants, of anthropogenic nature (Checklist, number 2.6), considered as risk of harm to human health and/or to the environment?

If either one or more than one of these four questions is answered by 'yes' the site should be regarded as a 'probably contaminated site'. If all of these four questions are answered by 'no', and there is no actual indication of significant contamination at the site, the site should not be regarded as a 'probably contaminated site'.

The evaluation is visualised in the flowchart below.

Figure I-1.3: Flowchart for evaluation of probably contaminated site in Step 1



1.3 Step 1 output

The output of this Step is the decision record for the conclusion as to whether or not the site is regarded as a probably contaminated site. If yes, further assessment may be undertaken. This assessment is described in the following Section, on Step 2, Preliminary investigation. The data on the site and the decision record should be included in the database of contaminated sites.

If the site does not qualify as a probably contaminated site it is not necessary to continue the assessment process in Step 2. The data on the site and the decision record can be submitted into the archives.

Volume I

Step 2 Preliminary investigation

Task 2.1 Preliminary site assessment

Step 2: Preliminary investigation

Task 2.1: Preliminary site assessment

2.1.1 Introduction to and scope of Task 2.1

General description and connection to other Steps
Step 2 concerns the preliminary investigation of individual sites which have been recognised as probably contaminated sites during the previous Step 1. The purpose of the preliminary investigation is to establish whether or not a site should be regarded as a contaminated site as defined in Box I-2.1.1.

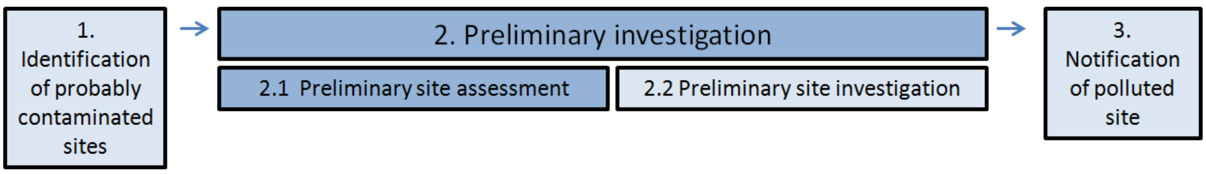
Box I-2.1.1 Definition of a contaminated site

A contaminated site is a delineated area consisting of aggregation of contamination sources, the areas between contamination sources, and areas that may contain contaminants due to migration from contamination sources.

If on the basis of preliminary site assessment or preliminary site investigation or detailed site investigation, the constituents and characteristics of contaminants discharged or otherwise come to be located at the site, exist at or above Response levels and in conditions including possible combination of contaminants and interaction between contaminants and/or environmental constituents which pose existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity, in such case the site may be determined as contaminated site.

This is the second step in the process of assessment and (possible) remediation of a site that could be a contaminated site. Step 2 is divided into two tasks: preliminary site assessment (Task 2.1) and preliminary site investigation (Task 2.2).
The objective of Task 2.1 preliminary site assessment is to focus as quickly as possible on imminent threats to human health and/or the environment to verify if the site is a contaminated site.

The figure below shows how this Task 2.1 is connected to the preceding and subsequent steps and tasks within the sequence of site assessment and remediation.



Activities
Within this task the following activities are to be performed:

1) A desk study is carried out on the available information of the site. Information in reports and petitions is assessed and new information is inventoried.

2) A site inspection is carried out to verify the information of the desk study and to prepare a plan for sampling and testing.
3) At the locations where main sources of contamination and relevant pathways to possible affected receptors are expected limited sampling and testing is carried out.
4) The results are compared with the Screening and Response levels and a conclusion is drawn as to whether or not the site should be regarded as a contaminated site. Recommendations on the necessity to carry out preliminary site investigation (Task 2.2) and specific aims of that investigation are presented.
5) Reporting of results of the preliminary site assessment and review of the report.

Responsible Parties
This activity is typically carried out by technical specialists of the specialized agency/consultant appointed to carry out the preliminary investigation. The work should be supervised by a senior colleague, and close cooperation with the competent authority is necessary to collect important information during the desk study and to prepare the site inspection and sampling.

The team involved should demonstrate in-depth knowledge and experience in the assessment of contaminated sites, including interpretation of topographic and geological maps and reports. The field work team should have relevant expertise, experience and skills for the site inspection and sampling. The laboratory work has to be carried out by an accredited lab.

2.1.2 Guidance for performing the activities of Task 2.1

This section presents concise guidance for the performance of the activities within Task 2.1. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

The detailed information on the execution of the preliminary site assessment can be found in section Volume III-2.1-i of this Guidance Document. This section comprises the Site Inspection Protocol (SIP) which contains several elements:
- General introduction on the use of the SIP;
- Checklists and manuals for execution of the individual activities;
- Recommendations for proper health and safety measures during the site visit and for reporting the results.

The SIP is related to the information inventoried and summarized in the database of contaminated sites. The information in this database enables the prioritization of sites in a program for remediation of polluted sites.

Activity 1 – Desk study

A review of the site information within reports, petitions and complaints obtained at Step 1 is performed (refer Box I-2.1.2 below). It is necessary to have as much information as possible concerning the history and land use both on site and off site (representing the surrounding area). This information indicates the possibility of the presence of contamination at the site.

Box I-2.1.2 Practical tip: Importance of desk study

It is very important to focus attention on the desk study at this stage of the process of assessment and remediation. If sources of contamination are not recognised it can lead to under-estimation of the extent of potential contamination and potential risks to receptors may not be recognized.
Furthermore, this can lead to unexpected problems during future site activities e.g. when reconstruction or reuse of the site will necessitate digging in subsoil or extraction of groundwater.

In addition an incomplete inventory of contamination sources and exposure pathways can lead to ineffective remediation plans. There are many examples of projects where, unfortunately, remediation activities had to be re-designed, causing exceedance of budgets and in some instances the remediation objectives previously agreed were not achieved.

The points below should be considered when assessing existing primary data:
- determine what data are available;
- evaluate purpose and scope of previous investigations;
- review sampling locations, dates, depths and sample descriptions;
- evaluate the sampling results and hazardous substance concentrations;
- review field preparation and collection techniques for previous samples;
- review available laboratory documentation;
- assess usability of previous primary data.

The data review may identify gaps in the available data. Additional information can be obtained from maps, data bases or governmental information.

The available reviewed information and the newly collected information can be summarised in a table and information gaps should be indicated before the site inspection is carried out (refer *Volume III-2.1-i SIP, Appendix E, table 1 Existing and general information and table 2 Overall assessment of data and data gaps*).

Based on all the compiled information a work plan should be devised prior to the site inspection. This work plan should include all reconnaissance activities and identify the specific information to be collected e.g. sampling from drinking water wells, noting the local hydrogeology, estimating the population at risk, interviews with specific stakeholders (such as occupants, current or former owners, neighbours, manager, employees and government officials) etc.

On completion of the desk study a review should be carried out to confirm whether there is any indication of contaminating activities at the site. If it is established that there is no such indication it should be concluded that the information from step 1 is incorrect. The site should be classified as 'not a probably contaminated site' and the database should be revised accordingly. Further investigation activities should not be regarded necessary for the site.

Activity 2 – Site inspection

The site inspection is a field visit to observe the site and the potential sources of contamination (on-site reconnaissance) and to undertake a perimeter survey of the facility as well as a survey of the local site environs (off-site reconnaissance). During this site inspection information is obtained to fill the gaps and the existing available information is verified. If possible photographs should also be taken.

The site inspection needs to be prepared by arranging access to the site and in consultation with important stakeholders. Furthermore, equipment, e.g. for sampling, needs to be prepared. Interviewing relevant stakeholders is an integrated part of the preliminary site assessment. Whether or not to include interviews with stakeholders at district, state and national level may involve the weighing of economic aspects. As a result, this may only be applicable to large scale sites.

Stakeholder	**Interview objective**	**Level**
Site owner	collect information, verify data	site
Site operator's health facility director	collect information, verify data	site
Local businesses, residents and NGO's	collect information, verify data	site and direct vicinity
Municipal authorities, including Water Supply and Sanitation	collect information	local
District administrator	collect information, e.g. on land ownership	district
State authorities, including SPCB and Groundwater Authority	collect information	state

During the site inspection health and safety guidelines have to be taken into account (refer *Volume III-2.1-i SIP, section 3*).

The information gathered during the site inspection should be summarized in tables (refer *Volume III-2.1-i SIP, section 5 –on-site- and 6 –off-site-*) and a sketch map should be drawn showing the principal recorded occurrences and expected sources of contamination the main exposure and migration pathways of pollutants and the locations of receptors.

Activity 3 – Limited sampling and testing

An initial assessment of the contamination present at the site may be ascertained from samples taken during the site inspection. These samples should be obtained from locations where the main sources of pollution are expected, and at locations within migration pathways. Because only a limited number of samples are obtained, the sample locations should be well chosen, and guidance is provided in Box I-2.1.3 below.

The sampling should be carried out according to the Sample Protocol (refer *Volume III-2.1-i SIP, Appendix A*).

The samples should be tested in a laboratory to assess the levels of contamination present. Laboratories should operate in accordance with specific accreditation criteria (refer *Checklist prequalification for site investigation including ToR, Volume II-2.1-a*).

Box I-2.1.3 Practical tip: Possible locations for sampling

Possible locations for sampling of sources and pathways:

- visual indication of cause of pollution such as the presence of (former) industrial process equipment, storage tanks, broken pipelines, etc;
- visual evidence of hazardous material by means of colour or odour or the composition of material, or uneven ground surface;
- reported location with confirmed high concentration levels in previous sampling results;
- where an incident (spill / uncontrolled release) has occurred identified by a former employee of a company;
- areas which can easily be accessed by humans and areas of sensitive use (residential, playground, agriculture);
- drinking water wells downstream of the site (to collect groundwater samples to assess if this pathway is contaminated);
- surface water at or near the site if expected to be contaminated by hazardous waste material;
- at discharge points with noticeable contamination an effluent sample should be taken;
- in cases of sites with effluent discharges a 'source sample' should also include a sample of the sediment.

The parameters for determination within each sample scheduled for analysis will depend on the hazardous waste material potentially present (refer *Volume III-2.1-i SIP, Appendix C*). For the various activities representative tracer components have been described. The tracer components can be seen as components of concern. If there is existing information about contaminants from previous investigations, this information should be used to select tracers. It has to be stated that not all the listed tracers necessarily have to be analysed at a site, but the list can be used as a starting point for the assessing analysis program at a specific site.

Figure I-2.1.1a: Sampling of groundwater (picture by COWI, Kadam)

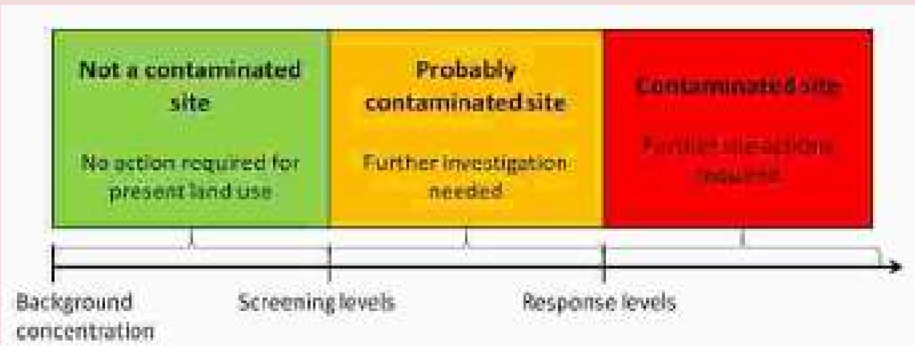
Activity 4 – Comparing testing results with standards

The laboratory testing will result in a list of concentration levels for various parameters / substances. These concentration levels have to be compared with the Screening levels and the Response levels (refer *Volume II-2.1-b*). A brief explanation on these levels is provided in Box I-2.1.4.

Box I-2.1.4 Explanation: Screening levels and Response levels

Screening levels are generic concentrations of hazardous substances in soil and sediments, groundwater and surface water at or below which potential risks to human health or the environment are not likely to occur and where no further investigation and assessment is needed. These Screening levels are distinguished for land use.

Response levels are generic concentrations of hazardous substances in soil and sediments at or above which it is very likely there is threat to human health or the environment, that may be imminent. At or above this level some form of response is required to provide an adequate level of safety to protect public health and/or the environment.



Note that that for certain contaminants such as Persistent Organic Pollutants, no background concentrations should be used, as there is no natural background for these substances.

The outcome of the comparison will determine whether or not the site should be regarded as a contaminated site (refer to definition in Box I-2.1.1). The following situations can occur:

- If the concentration level of one or multiple contaminants exist at or below Screening levels the site cannot directly be regarded as 'not a probably contaminated site'. This because of the fact that only a limited number of samples were taken. Further investigation is necessary to assess if there are any further sources of contamination at the site which may cause a risk to present or future land use. This can be done by a preliminary site investigation.
- If one or multiple contaminants exceed Screening levels but at or below Response levels the site may be determined as probably contaminated site. Then preliminary site investigation should be carried out as well. This is because of the fact that only a limited number of samples were taken and there may be other locations at the site where higher concentration of contaminants occur;
- If one or multiple contaminants exceed Response levels the site can be classified as a contaminated site. Often it is not clear if all sources and pathways have been identified and samples may not have been taken. In that case a preliminary site investigation is necessary. If it is clear that all sources and relevant pathways have been identified and samples were taken at these points, no preliminary site investigation is necessary. In that case the site may be notified directly as a contaminated site and prioritisation can take place (Step 3 and Step 4 of the assessment and remediation process).

All these situations are illustrated in the below result flowchart Figure I-2.1.3 for the comparison of concentration levels with Screening and Response levels.

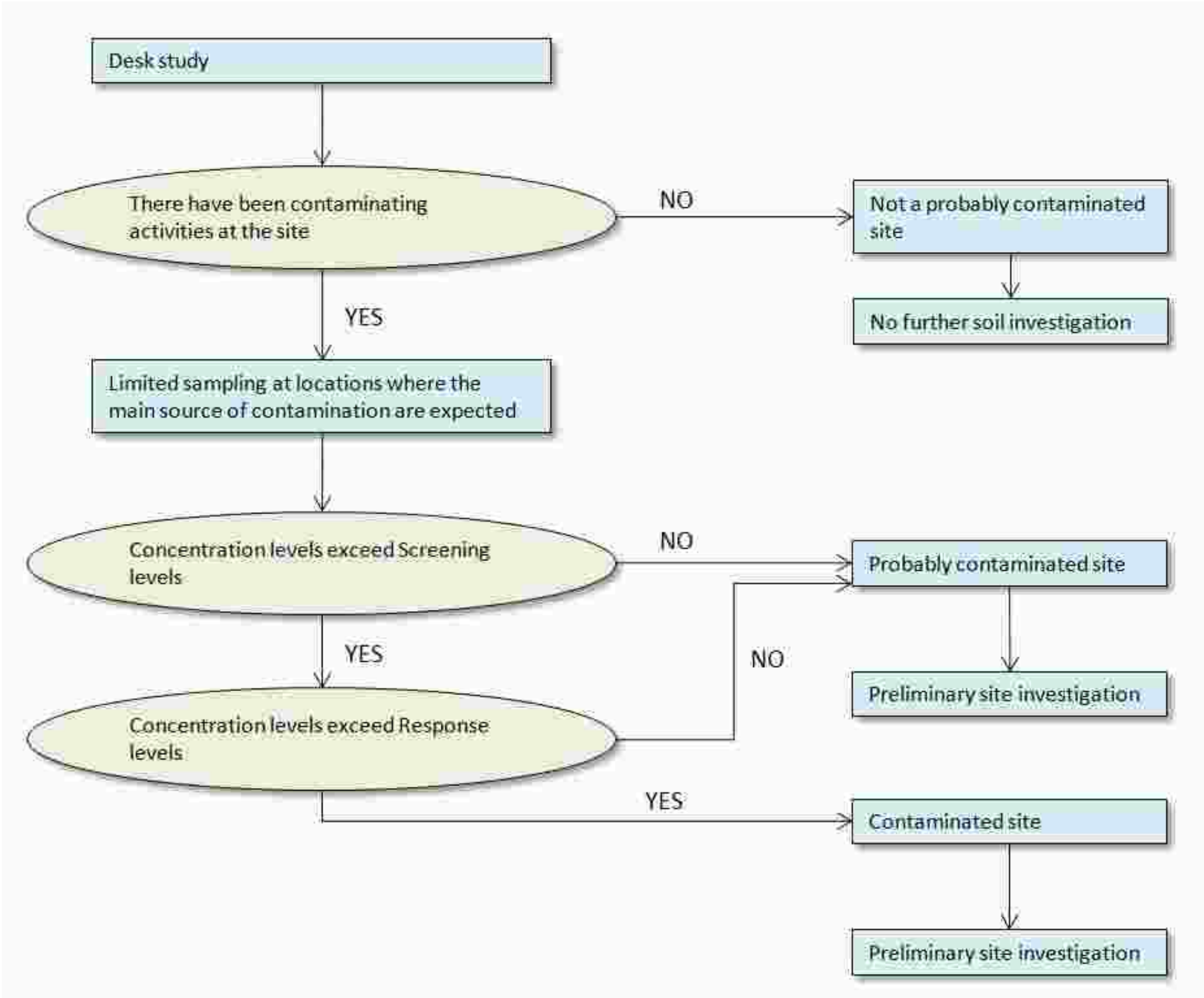
Activity 5 – Reporting and review

The activities carried out, the methods used and the results of the preliminary site assessment should be described in the report. The chapters of the report are structured in accordance with the stages of the investigation itself (refer *Checklist for preliminary site assessment report, Volume II-2.1-c*).

Finally, a conclusion should be drawn as to whether or not the site meets the definition of contaminated site. Recommendations should also be provided for the next step in the assessment and remediation process. If there is not enough information to draw a conclusion a recommendation for further investigation should be provided.

It is important that this document contains copies of the original sources of information in databases, previous reports and other sources. This is because at later stages of the assessment and remediation process, it is often necessary to revert to the original information when interpreting newly collected data.

Figure I-2.1.3: Preliminary site assessment result flowchart in Task 2.1



2.1.3 Task 2.1 output

The output of this task 2.1 is the conclusion whether the site should be regarded as a contaminated site. If so, or if there is not enough information, further investigation is necessary to obtain more information.

If the site is not regarded as a contaminated site, it is not necessary to continue the process of assessment and remediation of the site. The site information and the decision should be registered on the database.

Volume I

Step 2 Preliminary investigation

Task 2.2 Preliminary site investigation

Step 2: Preliminary investigation

Task 2.2: Preliminary site investigation

2.2.1 Introduction to and scope of Task 2.2

General description and connection to other Steps
Step 2 concerns the preliminary investigation of individual sites which have been recognised as probably contaminated sites during the previous step 1. The purpose of the preliminary investigation is to establish whether or not a site should be regarded as a contaminated site as defined in Box I-2.2.1.

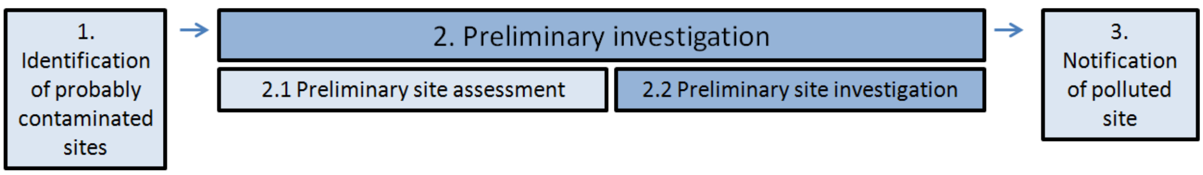
Box I-2.2.1 Definition of a contaminated site

A contaminated site is a delineated area consisting of aggregation of contamination sources, the areas between contamination sources, and areas that may contain contaminants due to migration from contamination sources.

If on the basis of preliminary site assessment or preliminary site investigation or detailed site investigation, the constituents and characteristics of contaminants discharged or otherwise come to be located at the site, exist at or above Response levels and in conditions including possible combination of contaminants and interaction between contaminants and/or environmental constituents which pose existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity, in such case the site may be determined as contaminated site.

This is the second step in the process of assessment and (possible) remediation of a site that could be a contaminated site. Step 2 is divided into two tasks: preliminary site assessment (Task 2.1) and preliminary site investigation (Task 2.2). The objective of the preliminary site investigation is to identify all sources of contamination and the relevant pathways linking them to the receptors of concern.

The figure below shows how this Task 2.2 is connected to the preceding and subsequent steps and tasks within the sequence of site assessment and remediation.



Activities
Within this task the following activities are performed:
1) Design of the investigation and testing strategy
2) Fieldwork and laboratory testing
3) Comparison of the test results with standards
4) Reporting of the preliminary site investigation and review of the report.

Responsible parties
This activity is typically carried out by technical specialists of the specialized agency/consultant appointed to carry out the preliminary investigation. The work should be supervised by a senior colleague. Cooperation with the site owner and competent authority is necessary to prepare the field work and to grant access to the site.
The team involved should demonstrate in-depth knowledge and experience in the assessment of contaminated sites and interpretation of information obtained from reports and maps on the topography and geology of a site. The field work team should have relevant expertise, experience and skills for the site inspection and sampling. The laboratory work has to be carried out by an accredited lab.

2.2.2 Guidance for performing the activities of Task 2.2

This section presents concise guidance for the performance of the activities within Task 2.2. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Because the preliminary site investigation is a follow up of the preliminary site assessment a lot of information on the execution of the preliminary site investigation can be found in the Site Inspection Protocol (SIP) (ref. *Volume III-2.1-i*). This SIP comprises:
- General introduction on the use of the SIP;
- Checklists and manuals for preparation and execution of the individual activities;
- Recommendations for proper health and safety measures during the site visit and for reporting the results.

The SIP is related to the information inventoried for a database on probably contaminated sites. The information held in this database enables the prioritisation of sites in a program for remediation of polluted sites.

<u>Activity 1 – Investigation strategy</u>

The starting point of the preliminary site investigation is a review of the output from the preliminary site assessment. The desk study information within the preliminary site assessment should already provide a detailed history of the site use.

The potential sources, pathways and receptors of concern should be established based on previous reports or petitions, maps, records, aerial photographs and interviews with owners or other informed parties. If there is doubt on the results of the desk study during the preliminary site assessment or if the report cannot be regarded as valid anymore, parts of the desk study should be carried out again. Depending on the land use and changes in land use, a period of 5 years can be used as a rule of thumb as the period for carrying out a new desk study.

During the preliminary site assessment the activities of the fieldwork have been focussed on locations where the highest contaminant concentrations were expected and the locations of the most sensitive land use. For the preliminary site investigation it is necessary to verify all potential sources, pathways and receptors at the site.

The investigation strategy to achieve this objective efficiently starts with the typology of the contaminated site (see Box I-2.2.2 for a short explanation of typology of contaminated sites. For a more detailed explanation we refer to the Glossary in the Annex of this Volume I). For each type of contamination a different investigation strategy is provided and from that points of attention for the fieldwork and laboratory work are specified in the *Protocol investigation strategy preliminary site investigation (*ref. *Volume III-2.2-ii).*
Note: at any contaminated site more than one type of contamination can occur. For each type of contamination and for each source a separate investigation strategy can be developed.

Box I-2.2.2 Explanation: Typology of contaminated sites

Contaminated sites are delineated areas in which toxic and hazardous substances exist at levels and in conditions which pose existing or imminent threats to human health or the environment. These sites often pose multi-faceted health and environmental problems. They can impact all components of the environment, particularly surface waters, soils, and groundwater and can result in people being knowingly or unknowingly exposed to toxic substances. Contaminated sites may include production areas, landfills, dumps, waste storage and treatment sites, mine tailings sites, spill sites, chemical waste handler and storage sites. These sites may be located in residential, commercial, industrial, rural, urban, or wilderness areas. All these elements are combined in a typology of contaminated sites. This typology is of importance for the assessment and design process of remediation.

The following main types of contaminated sites are distinguished based on the causing activity and pathway of spreading of contamination:

Source related:
- Type S1: Land bound solid phase contamination
- Type S2: Water bound sediments solid phase contamination
- Type L: Land bound liquid phase contamination

Pathway related:
- Type P1: NAPL contaminants in soil (Non Aqueous Phase Liquids)
- Type P2: Groundwater contaminations

Note: depending on a specific situation, a combination of these types may be possible. Example: a land bound storage of chromium containing hazardous waste (type S1), causing leachate of chromium to groundwater and leading to a contaminated groundwater plume (type P2).

Further explanation on the typology is provided in the Glossary.

If additional site specific information is available the general type can be made more site-specific by developing a Conceptual Site Model (CSM). The CSM supports the investigator to visualize the possible sources, pathways and receptors relevant at the site. See Box I-2.2.3 for a short explanation of the Conceptual Site Model. For more detailed information how to apply the CSM refer to *Manual Conceptual Site Model an identifying the Source-Pathway-Receptor, Volume III-2.2-i*.

Box I-2.2.3 Explanation: Conceptual Site model

The Conceptual Site Model is a representation of the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors. It crystallises understanding of what needs to be done to achieve the investigation of contaminated sites, the assessment of risks and from this point appropriate remediation techniques to achieve remediation objectives.

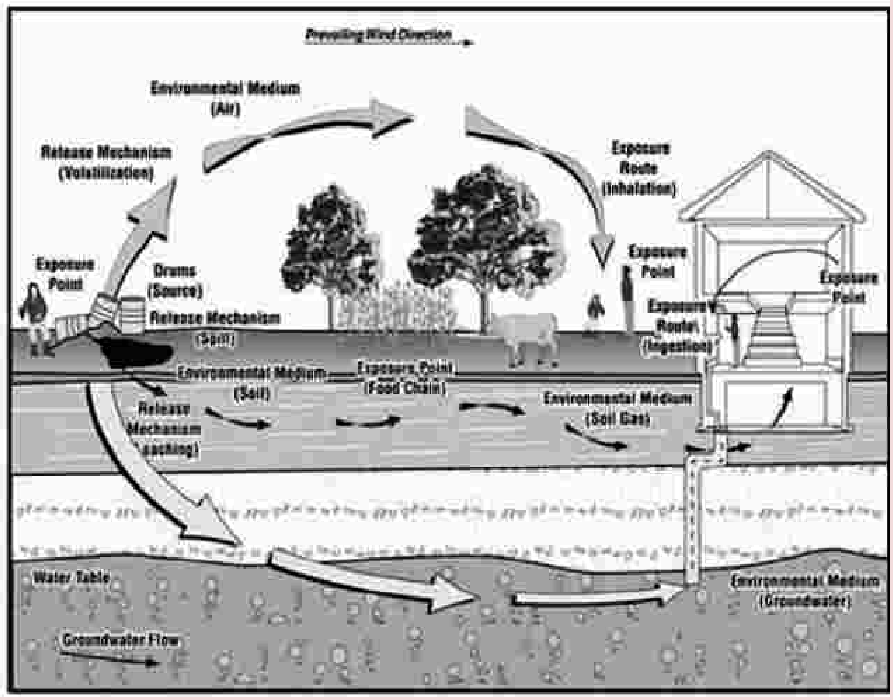


Figure I-2.2.1: Example of a schematic exposure pathway in a Conceptual Site Model (source: Public Health Assessment Guidance Manual, Agency for Toxic Substances and Disease Registry, 2005)

Based on the investigation strategy an investigation protocol is prepared, regarding assessment of the contamination levels of the source and identification of the major pathways and receptors of concern. This protocol should pay attention to the following elements:

- Screening and sampling technical equipment;
- Sampling pattern and depth of samples, number of samples, use of composite samples;
- Analytical test parameters / determinants required;
- QA/QC procedures such as use of field blanks/trips blanks, procedures to avoid cross contamination by sampling equipment etc.

Technical equipment for site assessment

Generally two ways of carrying out field investigation are distinguished: screening methods which provide an area-wide information and sampling methods at specific locations.

There are several screening methods that provide qualitative information from which the possible presence of contamination can be concluded. Some examples are illustrated in Box I-2.2.4 below. An overview of screening techniques is provided in the *Overview of techniques for site investigation, Volume III-2.2-iii.* This approach can help to provide a first rough indication of the source of contamination and delineation of a contaminated site.

Box I-2.2.4 Example Site screening methods

For recognition of the presence of heavy metals in soil or waste material an XRF device can be used. This equipment detects increased levels of heavy metals in samples.

For volatile organic components the use of a soil vapour survey technique can be helpful. A portable Photo-ionization Detector can detect these components in a soil or water sample.

For hydrocarbon site investigations a Cone Penetration Test (CPT) mounted UV fluorescence screening tool can be used for a quick reconnaissance of a site for hydro carbon contaminations.

Note.
Screening methods are often sensitive to side-effects caused by naturally occurring substances, the indirect type of measurement or the calibration shifting during the use of the screening tool. For instance i- the fluorescence sensor may deliver false positives in cases of high proportions of peat and other naturally occurring organic carbon or ii- a clay layer or saline groundwater body may be mistaken for a contaminated plume by a electromagnetic mapping (EM).
Verification and calibration procedures are tool or supplier specific.
It is especially necessary to align screening values with other data such as laboratory analyses and typically cannot be used as the only tool for data acquisition.

Based on the outcome of such screening methods additional sampling and testing is always necessary to provide quantitative results of the concentration levels of components in the soil, sediment, groundwater or surface water.

For groundwater sampling existing groundwater wells can be used, but sometimes it is not clear how the installations have been designed, and which stratum the groundwater is derived from. To obtain accurate information for a specific level new dedicated monitoring wells should be installed.
An overview of possible technical equipment for collection of samples (soil, sediment, surface water, groundwater) is provided in the *Overview of techniques for site investigation, Volume III-2.2-iii*.

Sampling pattern, number of samples and depth of samples
Knowledge of the possible location of contamination sources is important for defining the sampling pattern. Small areas where contaminated material is concentrated in one place (point source contamination) can be investigated during the preliminary site investigation by a few representative samples collected from one or two exploratory excavations. In case contaminated material is spread over a large area it is necessary to use a pattern of samples to collect representative information of the contaminated site. The *Protocol investigation strategy preliminary site investigation*

Volume III-2.2-ii provides a first indication of the sampling pattern and number of samples.

There are some additional aspects that should be taken into account when developing a sampling strategy for a specific site:

- Restrictions for investigation such as buildings, subsurface infrastructure and site boundaries;
- If possible some samples should be obtained for identification of background quality of soil, groundwater, sediment or surface water which has not been influenced by this particular contamination;
- Samples of groundwater may be obtained from selected existing observation wells in the aquifer beneath the surface of the site, for monitoring water level elevation and water quality at appropriate locations. The depth of the well and the filter (if any) should be known. If there is data from previous sampling or level measurements it is important to know the frequency and period relating to the hydrological environs (influence of monsoon).

Parameters for laboratory testing:
The parameters important for the investigation can be selected based on:

- Previous industrial operation processes or waste generation, discharges or disposal activities. The type of industry determines the parameters involved (ref. *Volume III-2.1-i SIP, Appendix C*).
- Specific observations during site inspection and field work of signs which indicate contamination not related to the above mentioned activities.
- Characteristics of the components regarding mobility or retardation. For assessment of groundwater quality the most mobile tracers are interesting to focus on. For sediments, components with high binding capacity are important to focus on when investigating a surface water body near to a former point of discharge.
- It is always recommended to test some samples for a broad spectrum of parameters. This because it is possible that there may have been polluting activities at the site that are either unknown or not documented in databases. These activities may possibly have caused contamination with different characteristics compared to the known activities.

<u>Activity 2 – Fieldwork and laboratory testing</u>

The fieldwork needs to be prepared by arranging access to the site and in consultation with important stakeholders. Furthermore, sampling equipment needs to be prepared.

The stakeholder consultation is needed, both to inform them on the fieldwork plan and to secure their support for the plan. The consultation may also yield information that can be useful in the final design of the fieldwork plan. Whether or not to include interviews with stakeholders at district, state and national level may involve the weighing of economic aspects. As a result, this may only be applicable to large scale sites.

Stakeholder	Interview objective	Level
Site owner	provide information, secure support	site
Site operator’s health facility director	provide information, secure support	site
Local businesses, residents and NGO’s	provide information, secure support	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	provide information, secure support	local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	provide information, secure support	state
For large scale site: national authorities, including Surveyor of India and Central Ground Water Board	collect information	national

During the site inspection health and safety guidelines have to be taken into account by the field team (ref. *Volume III-2.1-i SIP, section 3*).

The activities in the field should be described in a logbook of the field investigator. Detailed descriptions of each source and of relevant pathways and receptors should include:

- Regarding source: type, location, dimensions, sensory perceptions/observations of possible pollution (form or colour or smell or stressed vegetation);
- Samples should be taken of the soil, sediment, groundwater and/or surface water assumed to be most contaminated based on visual / olfactory evidence of contamination;
- Regarding pathway: depth of groundwater, presence of surface water and possible overland flow route from source to the nearest surface water body;
- Regarding receptors: dwellings, schools/playgrounds, use of groundwater wells, crops or cattle, other sensitive environments, land use in the vicinity.

Furthermore, the activities carried should be accurately described for inclusion in the report.
The descriptions should be accompanied by sketches of the site (location of sources, dimensions, distances to receptors, significant site features, with marking of north and scale. The locations of exploratory holes should preferably be indicated by XYZ-coordinates, using GPS.

Note: Always be flexible on fieldwork activities to maintain efficiency. Based on the initial field work results additional samples and testing may be appropriate in case of unexpected indications of pollution.

The sampling should be carried out according to the Sample Protocol (ref*. Volume III-2.1-i SIP, Appendix A*).
The samples should be tested in a laboratory to assess the levels of contamination in the sample. Laboratories should operate in accordance with specific accreditation criteria (ref. *Volume II-2.1-a*).

The parameters for determination within each sample scheduled for analysis will depend on the hazardous waste material potentially present (refer *Volume III-2.1-i SIP, Appendix C*). For the various activities representative tracer components have been described. The tracer components can be seen as components of concern. If there is existing information about contaminants from previous investigations, this information should be used to select tracers. It has to be stated that not all the listed tracers necessarily have to be analysed at a site, but the list can be used as a starting point for the assessing analysis program at a specific site.

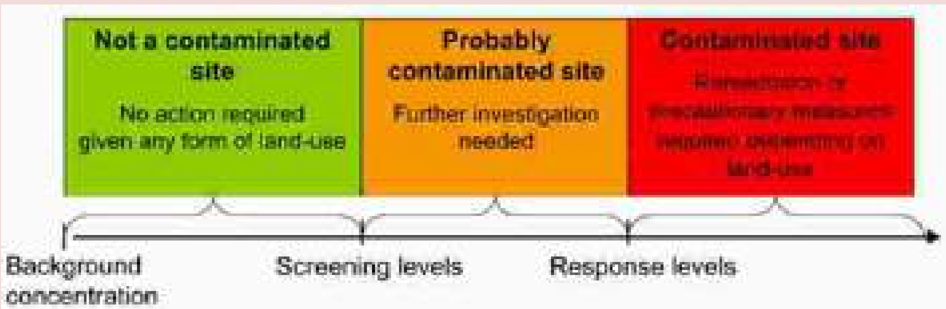
Activity 3 – Comparison of testing results with standards

The laboratory test results should be tabulated and recorded in terms of concentration levels for each parameter / substance per sample. These concentration levels are compared with the Screening levels and the Response levels (ref. *Volume II -2.1-b*). A short explanation on these levels is provided in Box I-2.2.5 below.

Box I-2.1.4 Explanation: Screening levels and Response levels

Screening levels are generic concentrations of hazardous substances in soil and sediments, groundwater and surface water at or below which potential risks to human health or the environment are not likely to occur and where no further investigation and assessment is needed. These Screening levels are distinguished for land use.

Response levels are generic concentrations of hazardous substances in soil and sediments at or above which it is very likely there is threat to human health or the environment, that may be imminent. At or above this level some form of response is required to provide an adequate level of safety to protect public health and/or the environment.



Note that that for certain contaminants such as Persistent Organic Pollutants, no background concentrations should be used, as there is no natural background for these substances.

The outcome of the comparison will define if the site should be regarded as a contaminated site (refer to definition in Box I-2.2.1). The following situations can occur:

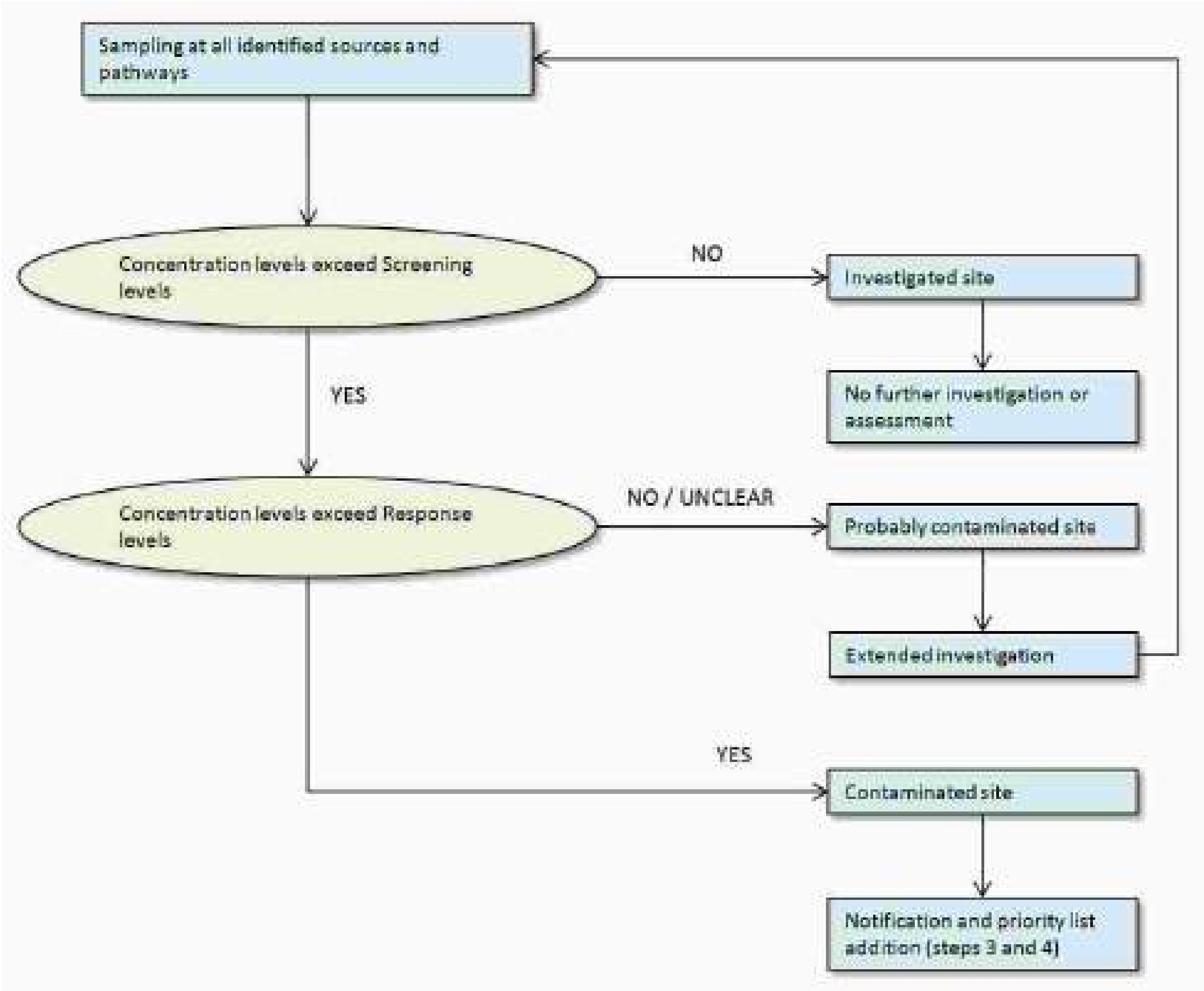
- If concentration levels of contaminants in all samples do not exceed Screening levels it can be concluded that there is no imminent threat to human health and/or the environment and the site can directly be regarded as 'investigated site' which has not proven to be contaminated. There has been sufficient investigation undertaken and further investigation or assessment of the site is not necessary.

- If concentration levels exceed the Screening levels but are lower than Response levels it is not directly possible to determine the site as a 'contaminated site' or as 'not a contaminated site'. If the outcome of the preliminary site investigation is not clear further investigation using elements of the detailed site investigation (Task 5.1) may be recommended.
- If concentration levels exceed Response levels it can be concluded that imminent threats to human health and/or the environment may occur and the site may be classified as a contaminated site. The site should be notified and prioritisation should be carried out (Step 3 and Step 4 of the assessment and remediation process).

All these situations are illustrated in the below result flowchart Figure I-2.2.3 for the comparison of concentration levels with Screening and Response levels.

In some areas the natural background levels may be higher compared to the Screening levels, e.g. the natural background levels of metals and other inorganic chemicals can vary widely and this should be taken into account when applying the Screening levels. Where it can be demonstrated that natural background concentrations are elevated (e.g. heavy metal concentrations in mineralised areas), it would be appropriate to develop less stringent assessment criteria. However care needs to be taken when establishing the level of the natural background and its natural variation as the local background may be influenced by historic mining and/or waste disposal activities.
For some contaminants such as Persistent Organic Pollutants, no background values should be used, as there is no natural background for these substances.

Figure I-2.2.3: Preliminary site investigation result flowchart in Task 2.2



Activity 4 – Reporting and review

Details of all activities carried out, the equipment and methods used and the results of the preliminary site investigation should be included in the site investigation report. The chapters of the report should be arranged in the same sequence of the investigation activities (ref. *Checklist for preliminary site investigation report, Volume II-2.2-a*). The topics in this checklist may be used as elements in Terms of Reference for the investigation of a specific site.

The relevant elements of the previous report of the preliminary site assessment can be incorporated in the report of the preliminary site investigation, if still valid.
In the preliminary site investigation report all major sources, pathways and receptors of concern should be identified. It is very important to recognize if there are indications of ongoing hazardous waste generation or fresh waste disposal or discharge on the site. If that is the case the first step must be to prevent these activities from occurring before proceeding with the remediation investigation.

Furthermore the initial Conceptual Site Model should be reviewed and probably adjusted based on the results of the preliminary site investigation.
If enough data is available groundwater level contour maps may be developed in order to indicate the groundwater flow direction.

When interpreting the results of groundwater quality the possible influence of seasons should be taken into account, see Box I-2.2.6.

Box I-2.2.6 Practical tip: Seasonal Influences

Groundwater levels may vary due to the influence of rainfall or flooding causing replenishment of the shallow groundwater level. There can be an influence from surface water level changes on the groundwater level near water bodies. Rising surface water in monsoon periods will cause an increase of the groundwater level. Changes in groundwater level can impact contamination distribution and concentration in soil and groundwater. Constituents bound to soil particles may be released and may be dissolved into groundwater causing increasing concentration levels. After a while equilibrium will be restored with a new balance between bound and dissolved particles so the concentration level remains the same until further changes in groundwater level occur. Groundwater level varying over the season in this way may cause periodical increasing and decreasing contamination concentration levels. They as well may have an effect on light non-aqueous phase liquids (LNAPL) on the groundwater surface which tend to reduce in thickness or disappear when water levels rise.

Although the primary purpose of a preliminary site investigation has not been to delineate the contamination it is often possible to provide a rough estimate of the extent of and boundaries of the contamination. When interpreting the data it may appear that several zones of distinct contamination may be present within the single contaminated sites. Each may be sufficiently distinguished to represent a contaminated site in it's own right. This is important for the legal notification of the contaminated site (step 3).

Finally a conclusion has to be drawn if the site has to be regarded as a contaminated site or not. Recommendations should be provided for the next step in the remediation process. If there is not enough information to draw a conclusion a recommendation for further investigation should be provided. The report has to contain as much as possible verifiable information meaning that copies of all original data from desk study, site inspection, field work and laboratory testing should be provided in annexes.

The investigating agency should ensure appropriate quality assurance protocols and systems have been adhered to including prescribed protocols, the calibration of field instruments, proper sampling and collection techniques and by providing records of responsibility, non-conformity events, corrective measures and data deficiencies.

The report is then reviewed by the competent authority regarding contaminated sites, ref. *Checklist review and approval preliminary site investigation report, Volume II-2.2-b*.

2.2.3 Task 2.2 output

The output of this task is the conclusion whether or not the site should be regarded as a contaminated site. If so, the next steps of the process of assessment and remediation, Step 3 notification and Step 4 prioritization should follow in succession. After that the remediation investigation (Step 5) can proceed.

If the site is not regarded as contaminated site it is not necessary to continue the process of assessment and remediation of the site. The site information and the decision should be registered by submitting it into the database.

Volume I
Step 3 Notification of polluted site

Step 3: Notification of polluted site

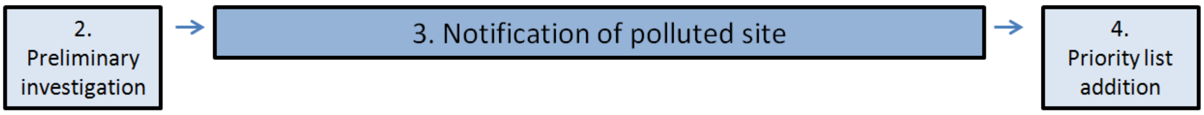
3.1 Introduction to and scope of Step 3

General description and connection to other Steps

Step 3 concerns the notification of a contaminated site by the competent authority as a 'polluted site' as defined in Box I-3.1 which requires remediation. Furthermore this notification has the effect of restricting further on-going activities at the site, depending upon the threats caused by the contamination.
Parallel to the above activities, parties responsible for contamination need to be identified and liability for the remediation and for paying the cost of remediation and rehabilitation of the affected environment and community needs to be assigned to them.

> **Box I-3.1 Definition of a polluted site**
>
> A polluted site means areas where hazardous substances exist at levels and in conditions which may pose existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living creatures, plants, micro-organisms, property, water quality or the environment in general, determined in the manner prescribed.

This is the third step in the process of assessment and remediation of a contaminated site.
The figure below shows how this Step is connected to the preceding and subsequent steps within the sequence of site assessment and remediation. Step 4 Priority list addition can be carried out parallel to this Step 3.



Activities

Within this step there are a number of activities to be performed. Most of these activities are on institutional, legal and financial aspects. For guidance on those activities we refer to the National Program for Remediation of Polluted Sites (Final Task 4 report, PWC Dec. 2015). Here, the guidance focuses on the technical aspects, and hence on the following activities:

1) Delineate the site;
2) Impose site use restrictions and temporary safety measures.

Responsible Parties

The activities in this step are typically carried out by technical, legal, financial and social specialists within the competent authority for the assessment and remediation process. The team involved should be able to interpret the technical information and recommendations of preliminary site investigation reports, and to link these properly to institutional, legal and financial consequences. Review is typically performed by senior staff members, to prepare the regulatory decision by the appropriate official.

3.2 Guidance for performing the activities of Step 3

This section presents concise guidance for the performance of the activities within Step 3. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

<u>Activity 1 – Delineate the contaminated site</u>

In order to notify a contaminated site as polluted site the boundaries of this site need to be established. Based on the preliminary site investigation report an overview of the contamination of a site is provided. All relevant sources, pathways and receptors of concern have been identified, described and preferably marked on a map. Although a preliminary site investigation is not intended for delineation of the contamination the collected information should provide a first indication of the contaminated area. This indicative information should be used to delineate the site. As these data will be used to notify a site, a decision with potentially far reaching consequences, proper care should be applied while performing this activity. When assessing the preliminary site investigation report it should be confirmed that the report contains at least the following elements:

- Sufficient data, both from historical sources as well as from the field, on the contamination situation in soil and sediment and, if applicable, in groundwater and surface water. These data should comprise at least the location of all samples and, if applicable, monitoring wells, a description of the stratigraphy and composition of the soil, the depth of the groundwater table, relevant observations from site inspection, and results of laboratory testing;
- Proper interpretation of all data and clear summary of the results;
- Conclusions, which can be related to the results.

Box I-3.2 provides some practical tips for the delineation of a contaminated site.

The data collected from official sources need to be verified through consultation of officials concerned with land matters.

Stakeholder	Interview objective	Level
Local authorities, including Patwari, Kotwal, Revenue Department	collect and verify information	local
District Collector	collect and verify information	district

When interpreting the data it may appear that the situation involves not one contaminated site, but several. In such a case, all identified contaminated sites need to be distinguished and assessed separately before notification can take place.

During the remediation investigation, Step 5 in the sequence of steps of assessment and remediation, further information will be developed so that more detailed delineation of the contaminated site from the surrounding area can be made.

Box I-3.2 Practical tip: How to delineate a contaminated site

The possibility for delineation of the contaminated site and the level of detail involved depends on the quality of the available information. It is always important to combine different pieces of information such as:

- The information collected during the desk study provides an indication of the situation of the presumed contamination at the site:
  - the industrial activities and the location of specific activities may indicate where typical waste material may be located and what will be the chemicals of concern;
  - the geological and hydrological characteristics may indicate the pathways of the contamination and where spreading of contamination is expected. Information about the time since polluting activities started and the permeability of the soil and the direction and speed of the groundwater flow may provide a first indication of the distance to where contamination might have spread. For contaminated sediment information of surface water flow is necessary to have an indication of the distance to where contamination might have spread;
  - the previous and current land use may indicate activities through which contaminated material can be moved or covered. This may have caused a totally different situation of the contaminated site than initially caused by the polluting activities.
- Maybe previous investigations already provide some information about the boundaries of the contamination.
- During site inspection sensory observation of contaminated material or information of effects of the contamination may indicate the presence of this material. If a presumed source of contamination is detected the surrounding area should be searched to find out where there is no indication of this material anymore. This can e.g. be the color of material lying at the surface, the shape and differences in height of the surface level or differences in vegetation. Combined with the results of the desk study a first rough conceptual site model (CSM) can be developed. In this CSM the area where contamination may be indicated.
- The preliminary site investigation report provides concentration levels of samples (soil, sediment, groundwater or surface water) which may indicate the locations where contaminated material is present and other locations where the levels do not exceed background concentration values. Possibly the sources of contamination presumed from the desk study can be confirmed.
- These results can support or contradict the conceptual site model, so this model can be updated incorporating the new information.

<u>Activity 2 – Impose site use restrictions and temporary safety measures</u>

Once a site has been notified this automatically sets in motion the next steps in the assessment and remediation process. It should be noted that often this sequence can take a lot of time, due to multiple reasons, e.g. the further investigation of the site and the preparation of the remediation may be technically complex or it may be necessary to carefully study remediation options before selecting the most effective and efficient option. Also, funding of the further assessment and remediation steps can take time. Furthermore, plans for redevelopment of the site or the surrounding area may define the moment when remediation works should start.

It may be that threats to human health or to the environment are assessed to be very severe, resulting in the need to rapidly respond to these threats. This can be the case if e.g. a clear relation can be made between the contamination of the site and current health problems of people living at or near the site (or in case this kind of threats is likely to occur in the very near future). If remediation works cannot start at short notice restrictions to the current site use and monitoring of the contamination should be considered.

By applying temporary safety measures the imminent risks caused by the contamination can be managed. An example of a temporary safety measure is to place fencing thereby implementing the site use restriction of prohibiting access.
If this leads to the necessity to make special arrangements for water and food supply the State Government may need to be involved.

A comprehensive overview of potential site use restrictions and temporary safety measures is presented in the *Checklist restrictions to site use and temporary safety measures, Volume II-3-a*.
Two examples of temporary safety measures are illustrated in the figures below.

Figure I-3.1: Example of fencing of a contaminated site

Figure I-3.2: Example of temporary safety measure to prevent new contamination from spill. The clamp is applied to stop a leak on a leaky pipe header running

3.3 Step 3 output

The output of this step is the site being notified based on the delineation and the conclusion whether there are site use restrictions which require the need of temporary safety measures. Further result of this step is information which relate to former contaminating activities and possible responsible parties.

Step 4 Priority list addition can be carried out parallel to this step 3. After that the remediation investigation (Step 5) can start.

If there is not enough information to delineate the site and as a result of that notification is found not be possible more detailed investigation should be considered.

Volume I

Step 4 Priority list addition

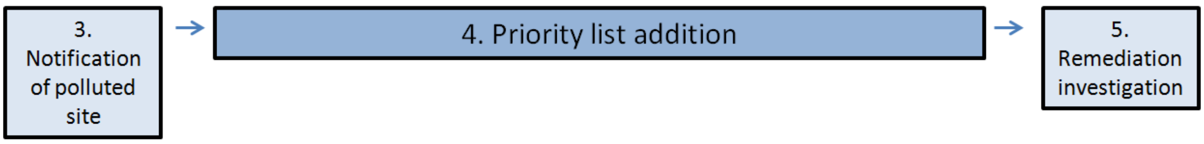
Step 4 Priority list addition

4.1 Introduction

General description and connection to other steps
Step 4 concerns the ranking of contaminated sites according to the priority their further investigation and remediation warrants, in comparison to other contaminated sites. This priority is related to the threat to human health and environment. A computerized database of priority sites with ranking features will be maintained and updated by the competent authority.

This section will discuss the technical aspects of this listing process, i.e. the application of prioritisation criteria to the parameters of a specific contaminated site. Step 4 commences with the assessment of relevant data on the site and ends with the presentation of a priority score for the site.

The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation. It should be noted that this Step may be performed in parallel with Step 3 Notification of polluted site.



Activities
A number of activities are performed in Step 4. In this document only the technical aspects to these are discussed:
1) Assess available data on the contaminated site;
2) Apply prioritisation algorithm to obtain priority score.

For detailed guidance on the prioritisation algorithm we refer to the Report of Prioritization of sites (part of NPRPS-Inventory and mapping of contaminated sites, COWI, Dec. 2015). The mentioned report includes explanation on two stages of prioritization. In this section we refer only to Stage II prioritization which is relevant for sites where a preliminary investigation has been carried out.

Responsible parties
The activities in this step are typically carried out by the competent authority for the assessment and remediation process. The team involved should demonstrate ability to interpret the information and recommendations of preliminary site investigation reports. This requires in-depth knowledge of and experience with the characteristics of contaminations (e.g. mobility, biodegradability) and its potential effects on humans and the environment.

4.2 Guidance for performing the activities of Step 4

This section presents concise guidance for the performance of the activities within Step 4. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Assess available data on the site

The first activity is to assess the available relevant data required for the prioritization system. Relevant parameters are listed in Table I.4.1 below. This table also indicates from which data sources these data may be retrieved.

Table I.4.1 Parameters relevant for prioritisation system

Parameter	**Data source**
On the source	
source concentration	site inspection or site investigation report
quantity of source	site inspection or desktop study
toxicity factor	Geoenviron Data Base
mobility factor	Geoenviron Data Base
On the pathway	
containment (access to contaminant)	technical judgement based on site access
attenuation reflecting directness of path to receptor	reflecting directness of path to receptor (including distance to receptor and groundwater vulnerability)
On the receptor	
land use	desktop study, site inspection
population at risk	desktop study, site inspection
sensitivity of receptor	site inspection
groundwater system at risk	Central Groundwater Boards, site inspection
surface water at risk	State Governments for Rivers, site inspection
sensitive ecosystems	scoring based on distance and type of sensitive ecosystems

The data collected from official sources need to be verified through consultation of officials concerned with land matters.

Stakeholder	**Interview objective**	**Level**
District Collector	collect and verify information	district

Activity 2 – Apply prioritisation algorithm to obtain priority score

In this activity the available data on the parameters listed in Table I.4.1 are processed in the prioritisation algorithm. To enable this, the data need to be converted into numerical values eligible to process the algorithm. Basic guidance for this is provided by table I.4.2 below.

Table I.4.2 Parameter values for prioritisation system

Code	Parameter	Scoring basis	Scoring range
On the source			
C	Source concentration	Marks as Low, Medium, High or ratio to Screening Level	0 – 10
Q	Quantity of source	Volume, or Low, Medium, High	0 – 5
T	Toxicity factor	A list of chemicals	0 – 5
M	Mobility factor	List of chemical characteristics	0 – 5
On the pathway			
F	Pathway Factor = containment * attenuation	 access to source directness to source	0.8 – 1 0.4 – 0.5 0.4 – 0.5
On the receptor			
L	Land use at the site	Low, Medium, High risk	0 – 10
P	Population at risk	log(pop) within 1 km radius or Low, Medium, High	0 – 10
S	Sensitivity of receptor	Low, Medium, High	0 – 30
G	Groundwater system at risk (use/importance of aquifer)	Low, Medium, High	0 – 10
SW	Surface Water at risk (use/importance of surface water)	Low, Medium, High	0 – 10
E	Sensitive ecosystems	Distance to designated reserves, etc.: Low, Medium, High	0 – 5

Once the data on the parameters have been converted into a score within the scoring range these scores can be applied into the following prioritisation algorithm:

Priority score = [C + Q + T + M](F) + [L + P + S + G + SW + E]

The *Checklist information for application prioritization system Volume II-4-a* provides additional guidance on the parameters needed to effectively use the prioritisation system.

Figure I-4.1: Example of contaminated material at the surface

Figure I-4.2: Example of possible receptors at contaminated site

4.3 Step 4 output

The output of this Step 4 is a priority score for the contaminated site at hand, which should be used to prioritize the site in relation to other contaminated sites and subsequently to include the site at the Priority list.

Volume I

Step 5 Remediation investigation

Task 5.1 Detailed site investigation

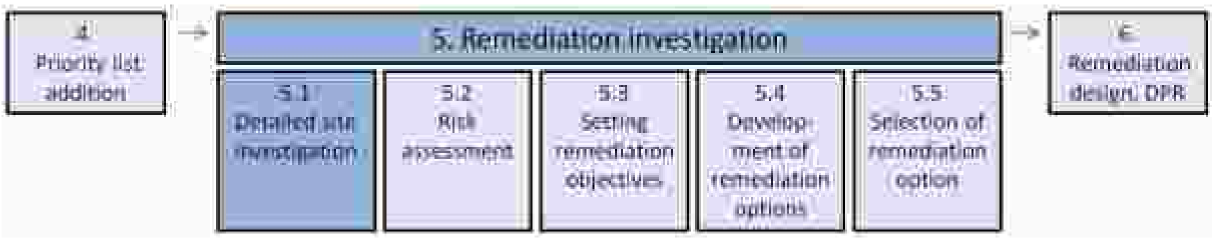
Step 5: Remediation investigation

Task 5.1: Detailed Site Investigation

5.1.1: Introduction to and scope of Task 5.1

General description and connection to other Steps and Tasks
Task 5.1, Detailed Site Investigation, concerns the identification of the nature, extent and concentrations of the substances at the contaminated site and of the site conditions. The results provide key information for risk assessment and the development of remediation options.

The figure below illustrates how this task 5.1 is connected to the preceding and following Steps and Tasks in the sequence of site assessment and remediation. The risk assessment may be developed sequential to the detailed site investigation and the results may be combined in one report.



Activities
The following activities are performed in Task 5.1:

1) Investigation strategy
2) Fieldwork and laboratory testing
3) Analysis and interpretation of exploratory data
4) Reporting detailed site investigation

Responsible Parties
This activity is typically carried out by technical specialists of the specialized agency/consultant appointed to carry out the site investigation. The work should be supervised by a senior colleague. Cooperation with the site owner and competent authorities is necessary to prepare the field work and to grant access to the site.
The team involved should demonstrate in-depth knowledge and experience in the investigation of contaminated sites and interpretation of exploratory results in relation to information obtained from reports and maps on the topography and geology of a site. It may be required to involve experts on modelling groundwater flow and subsurface transport of contamination.
The field work team should have relevant expertise, experience and skills for the site inspection and sampling. The laboratory work has to be carried out by an accredited lab.
For complex issues regarding the interpretation of exploratory results research institutes may be involved.

5.1.2 Guidance for performing the activities of Task 5.1

This section presents concise guidance for the performance of the activities within Task 5.1. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Investigation strategy

The starting point of the detailed site investigation is to define the scope for the investigation and to establish the required information. The detailed site investigation is generally aimed at:

- Providing comprehensive information on the nature, extent and concentrations of the substances at the contaminated site:
  - delineation of the area of the identified contaminating substances in soil, groundwater, sediment or surface water, related to the sources of contamination at the notified contaminated site (Step 3);
  - location and contours of concentration levels of the contamination;
  - assess contaminant dispersal in soil, groundwater, surface water, sediments, air and dust, direction and speed of spreading
- Providing information on the site conditions to identify and assess all contaminant pathways with respect to assess risks (refer to Task 5.2 for Risk assessment) such as a comprehensive geological and hydrogeological assessment;
- Providing information on site conditions to assess possible options for remediation (refer to Task 5.4 for Development of remediation options), e.g. permeability of stratigraphic subsurface layers, density of soil material, or concentration of general parameters in groundwater (iron, related to groundwater abstraction techniques).

Information of the contaminated site already has been obtained by a preliminary site investigation which provides a detailed history of the site use and an identification of all major sources, pathways and receptors of concern. Although the primary purpose of a preliminary site investigation has not been to delineate the contamination an indication of the extent of and boundaries to the contamination should be described.

The Conceptual Site Model is a key element during this detailed site assessment. The CSM enables the investigator to visualize the possible sources, pathways and receptors and focus on the areas for investigation relevant at the site, refer *Volume III-2.2-i, Manual Conceptual Site Model and identifying the Source-Pathway-Receptor*, on how to apply the CSM.
In the preliminary site investigation (Task 2.2) the CSM already has been developed.

If there is doubt on the results of the preliminary site investigation or if the report cannot be regarded as valid anymore, parts of the desk study or identification of sources, pathways and receptors should be carried out again in the detailed site investigation phase. Depending on the land use and changes and the contaminated substances involved, a period of 5 years can be used as a rule of thumb as the period for carrying out an update of the preliminary site investigation.

Detailed site assessment is always a site specific exercise for which a specific investigation protocol should be developed. An example of the development of an investigation strategy is included in *Example investigation strategy detailed site investigation, Volume III-5.1-i*.

Based on the investigation strategy a detailed investigation protocol is prepared, regarding assessment of the contamination levels of the source and identification of the major pathways and receptors of concern. This protocol should pay attention to the following elements:

- Required information and data gaps;
- Screening and sampling technical equipment (refer *Overview of techniques for site remediation (Volume III-2.2-iii*), an example is illustrated in figure I-5.1.1 below;
- Sampling rationale and design (media, locations, pattern and depth of samples) and the required level of detail of information), refer to Box I-5.1.1 below for an example;
- Number of samples;
- Screening of observations wells or necessity for drilling new wells;
- Necessity for multisampling events;
- Methods for establishing stratigraphy and characteristics of subsurface layers;
- Analytical test parameters for determination required. Based on the chemicals of concern as reported in the preliminary site investigation. In addition parameters referring to risk assessment or the applicability of remediation techniques may be tested (e.g. inorganic chemistry to describe redox conditions and potential for natural degradation, macro ions for assessing water treatment, bacterial analyzes, etc.).;
- Restrictions for investigation such as buildings, subsurface infrastructure and site boundaries;
- Quality assurance and quality control procedures such as use of field blanks/trips blanks, procedures to avoid cross contamination by sampling equipment etc.

Box I-5.1.1 Example for sampling design

The spacing and number of sampling points depends very much on the situation of the contaminated site. Based on experience the knowledge has gained that no generic sampling designs and no minimum protocol should be applied during the detailed site investigation phase.

To explain the differences in design for two totally different situations of contamination an indication on the number of sampling points are mentioned:

- Top layer of soil contaminated with heavy metals on a site of 1 ha: to achieve a representative impression of the actual situation about 10 boreholes may be drilled and for every distinct soil layer (at least every 50 centimetres) a sample will be taken;
- Volatile hydrogen chloride contamination has infiltrated the soil into the base of the aquifer: applying a CSM is of major importance to understand how the contamination may be located in soil and groundwater. The number of sampling points is not simply related to the surface of the above example of a contaminated top layer. Maybe tens or even hundreds of samples may be necessary to delineate the contamination. Apart from the primary contaminant parameters other parameters are required to obtain information of the macro chemical and biological situation of the aquifer.

Figure I-5.1.1: example of field work: tripod for drilling boreholes and placing water wells

Elements for Terms of Reference for the detailed investigation of a specific site may be selected from the topics in the *Checklist for detailed site investigation report, Volume II-5.1-a*.

Activity 2 - Fieldwork and laboratory testing

The field work may be assigned to experienced fieldwork teams of third parties. Samples should be tested in a laboratory to assess the levels of contamination in the sample. Laboratories should operate in accordance with required accreditation criteria.
For the selection of third parties the *Checklist prequalification for site investigation including ToR, Volume II-2.1-a* may be used.

The fieldwork needs to be prepared by arranging access to the site and in consultation with important stakeholders. Furthermore, sampling equipment needs to be prepared.

The stakeholder consultation is needed, both to inform them on the fieldwork plan and to secure their support for the plan. The consultation may also yield information that can be useful in the final design of the fieldwork plan. Whether or not to include interviews with stakeholders at district, state and national level may involve the weighing of economic aspects. As a result, this may for the state and national levels only be applicable to large scale sites.

Stakeholder	Interview objective	Level
Site owner	exchange information, secure support	site
Site operator’s health facility director	exchange information, secure support	site
Local businesses, residents and NGO’s	exchange information, secure support	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	exchange information, secure support	local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	exchange information, secure support	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	exchange information, secure support	national

During the site investigation health and safety guidelines have to be taken into account by the field work team (refer *Volume III-2.1-i SIP, section 3*).
The sampling should be carried out by using the Sample Protocol (refer *Volume III-2.1-i SIP, Appendix A*).

The activities in the field should be described in a logbook of the field work team. The activities carried out should be accurately described for inclusion in the report.
The descriptions should be accompanied by sketches and pictures of the site (location of sources, dimensions, distances to receptors, significant site features, with marking of north arrow and scale. The locations of exploratory holes, wells or other observation points should preferably be indicated by XYZ-coordinates, using GPS.
Possible deviations from the original investigation protocol should be described in detail (refer Box I-5.1.2 below).

Box I-5.1.2 Practical tip: flexibility during field work

During field work activities certain observations may lead to considerations for deviation of the original investigation protocol. Therefore it is required to maintain flexible on fieldwork activities to achieve good results in an efficient manner. Based on the initial field work results additional samples and testing may be appropriate in case of unexpected indications of pollution. Multiple sampling events have to be taken into account and an iterative approach of detailed site assessment may be considered for efficiency reasons.

Activity 3 - Analysis and interpretation of exploratory data

Interpretation laboratory testing results against Screening and Response levels
The laboratory test results should be tabulated and recorded in terms of concentration levels for each parameter / substance per sample. These concentration levels are compared with the appropriate *Screening levels and the Response levels, Volume II -2.1-b*.

In some areas the natural background levels may be higher compared to the Screening levels, e.g. the natural background levels of metals and other inorganic chemicals can vary widely and this should be taken into account when applying the screening levels. Where it can be demonstrated that natural background concentrations are elevated (e.g. heavy metal concentrations in mineralised areas), it would be appropriate to develop less stringent assessment criteria. However care needs to be taken when establishing the level of the natural background and its natural variation as the local background may be influenced by historic mining and/or waste disposal activities.

Analysis of groundwater flow and assessment of contaminant transport
Contaminants released into the soil can work their way down through the unsaturated zone into groundwater and can create a contaminant plume within an aquifer. Transport in the aquifer is mainly caused by movement of water (advective transport and dispersion). Within the aquifer the contaminant is spreading over a wider area, its advancing boundary often called a plume edge, which can then intersect with groundwater wells and springs, making the water supplies unsafe for humans and ecology.
Various mechanisms have influence on the transport of contaminants in the aquifer, e.g. diffusion (which is important in case groundwater flow is limited and in case of dissolving of substances in water), adsorption and decay. Analysis of groundwater systems is the basis for a good understanding of the transport of contaminants. Therefore a conceptual site model has to be developed which includes the understanding of transport in the groundwater.

Contaminating fluids are seeping into the soil in a vertical direction. Depending on the density of the fluid it will spread (float) on top of the groundwater level, e.g. for mineral oil, of seep through the groundwater to reach an impermeable layer.

The stratigraphy of the area plays an important role in the transport of these pollutants. An area can have layers of sandy soil, fractured bedrock, clay, or hard pan. Areas of karst topography on limestone bedrock are sometimes vulnerable to surface pollution from groundwater. Therefore information from hydrogeological data and site specific soil profile descriptions are important.

For analyzing and mapping of the hydrogeological systems and spreading of contaminants a variety of direct and indirect information is required. For describing the regional systems these data are usually available in various databases. But for the shallow and very local systems (characteristic surfaces be 100 to 2500 m2) should be obtained through additional information.

Three types of information are required for compiling a complete hypothesis for the distribution of a contamination in a particular area:

1. geological and hydrological information of the subsoil: this involves the information of the whole area, but also information from boreholes etc. and expert knowledge about the relationship between the composition of the soil and the pattern of the spreading of the of contamination (hydrology);

2. Information on soil contamination: This relates to information about pollution in the area. This is data from soil information databases and reports, combined with expert knowledge about the spreading of the contamination;
3. other information of interest for carrying out the assessment, in particular the location of (drinking) water extraction.

The items below indicate the required parameters for hydrogeological investigation and prediction of spreading of contamination.

Geographical information of the subsoil:

- Presence, thickness and resistance / composition of a top layer, including:
  - risk of occurring of local (natural) changes in continuity
  - risk of occurring of excavation / disruption of the top layers (large buildings, drawn construction piles, tunnels, hydraulic head of the top and bottom layers)
- Thickness of the upper aquifer, including:◦
  - variability in thickness and composition of the aquifer
  - information on the groundwater flow and recharge of the aquifer
- Information on the hydrology, including:
  - Patterns of hydraulic head (isohypse maps), based on data over a period of at least one year
  - Replenishment of groundwater
  - Information on the geochemical characteristics of the geological layers: organic matter, clay matter, ironhydroxide, cation exchange capacity, sulfides, porosity, grading.

Information on known contaminants:

- Contaminants present in groundwater
- Characteristics of the substances: density, solubility, adsorption level
- Levels of contamination
- Depth of aquifer in which the contaminants are found, related to soil structure.
- Whether or not passage of the top layer has occurred
- Length and shape of ground water plumes, taking into account the age of the contamination
- Direction of spreading of the groundwater plumes
- Volume of groundwater plumes, taking into account the age of the contamination
- Information on the activity which has caused the contamination (type of industry/activity and scale and volume of used substances during process)
- Presence of floating layers (LNAPL) and sinking layers (DNAPL)

Site-specific information on distribution and spreading of contaminants:

- The degree of disturbance of the spreading of the plumes by groundwater extraction (e.g. for construction purposes).
- Is spreading through sewage system applicable in the present area?
- Multiple sources upstream of the site?

Other information:

Location and types of receptors (i.e. drinking water wells, areas of drinking water catchments, valuable ecosystems).

The results of measuring groundwater levels in observation wells should be outlined in a contour map. This should be combined with interpretation of the geological, hydrological and hydrogeological features of the site to estimate groundwater flow direction and speed.

For complex situations it may be required to carry out modelling of groundwater flow and contaminant transport and information on general geochemical parameters should be collected during fieldwork (refer to *Tools for risk assessment, Volume III-5.2-i*).

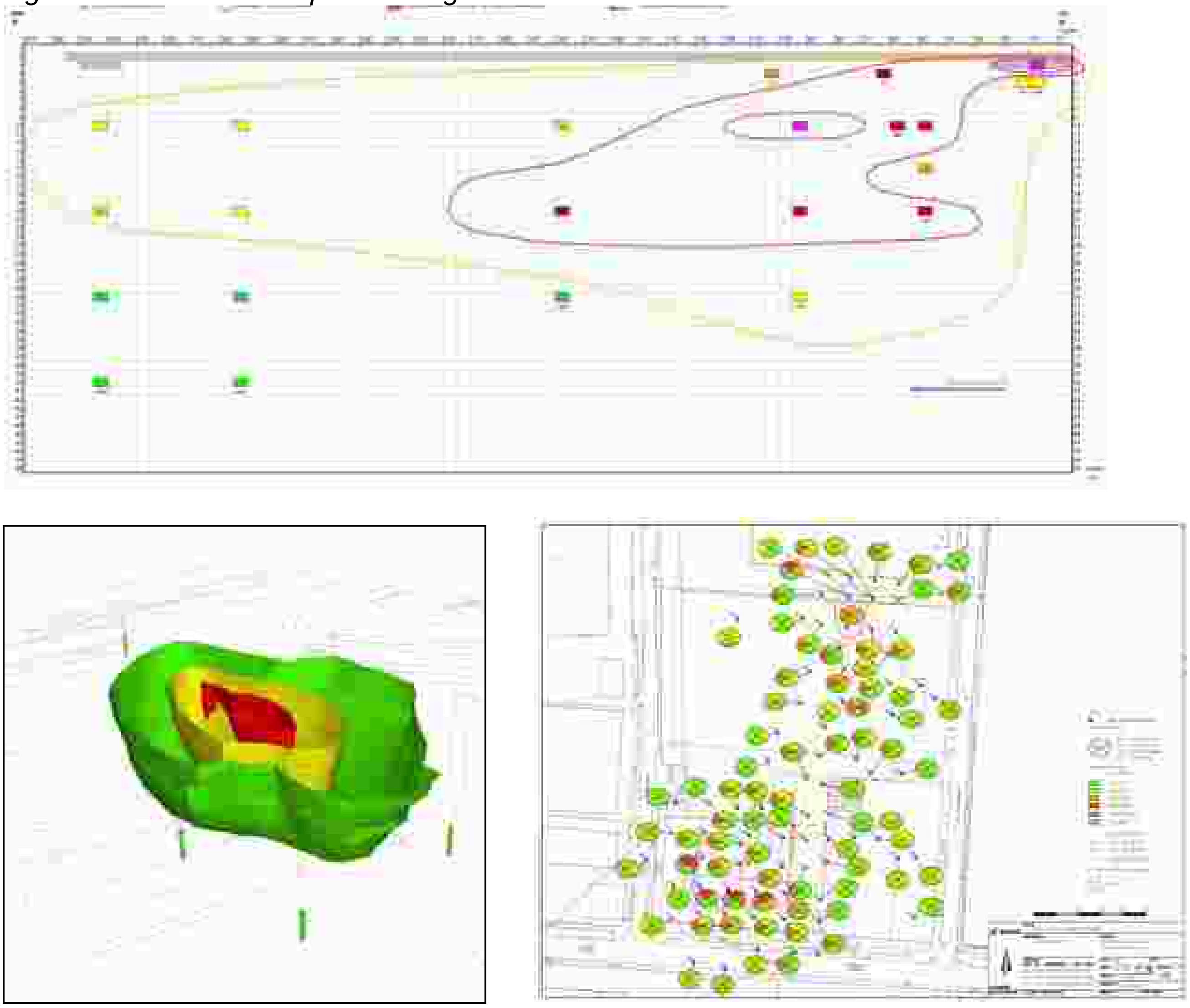
Activity 4 – Reporting detailed site investigation

Details of all activities carried out, the equipment and methods used and the results of the detailed site investigation should be included in the site investigation report. The chapters of the report should be arranged in the same sequence of the investigation activities (refer *Checklist for detailed site investigation report, Volume II-5.1-a*).

The relevant elements of the previous report of the preliminary site investigation should be incorporated in the report of the preliminary site investigation.
The Conceptual Site Model should be reviewed and adjusted based on the results of the detailed site investigation.

The extent and amount of contaminated material and the manner it has been migrated should be described and outlined trough maps. Concentration levels and delineation of contaminated soil, groundwater and sediment can be explained clearly in this way. More than one map and use of colors for different categories of concentration levels may be required for optimal result. If there are uncertainties they should be indicated clearly. It may be not necessary to fill all data gaps because the decision on the remediation may not be depending on it.

Figure I-5.1.2.a-c: example drawings of contamination situation



When interpreting the data it may appear that several zones of distinct contamination can be present within the single contaminated sites. Each may be sufficiently distinguished to represent a contaminated site in it’s own right. This is important regarding the confirmation of legal notification of the contaminated site which has taken place in Step 3.

Finally, a conclusion should be drawn regarding the predefined scope of the investigation. Recommendations should be provided for the next step in the remediation investigation process. If there is not enough information to draw a conclusion a recommendation for further investigation should be provided.

The report has to contain as much as possible verifiable information meaning that copies of all original data from desk study, site inspection, exploratory field work and laboratory testing and modelling should be provided in annexes.
The investigating organisation should ensure appropriate quality assurance protocols and systems have been adhered to including prescribed protocols, the calibration of

field instruments, proper sampling and collection techniques and by providing records of responsibility, non-conformity events, corrective measures and data deficiencies.

Before proceeding to the risk assessment and further steps in the preparation of remediation it is useful to discuss the results with the competent authority regarding contaminated sites.

5.1.3 Task 5.1 output

The output of this Task 5.1 provides clear information on the nature, extent and concentrations of the substances at the contaminated site and on the site conditions. A checklist of elements a detailed investigation report may contain is presented in *Volume II-5.1-a.*

The competent authority responsible for reviewing the risk assessment report may refer to the checklist mentioned above. First, it needs to be determined which of these elements are relevant for the situation at hand. The competent authority may then proceed by assessing whether the report contains all these relevant elements. Data in the report should be complete and presented clearly. Most importantly, the report should show that the data and other information underpin the conclusions and provide enough information for risk assessment and development of remediation options.

Volume I

Step 5 Remediation investigation

Task 5.2 Risk assessment

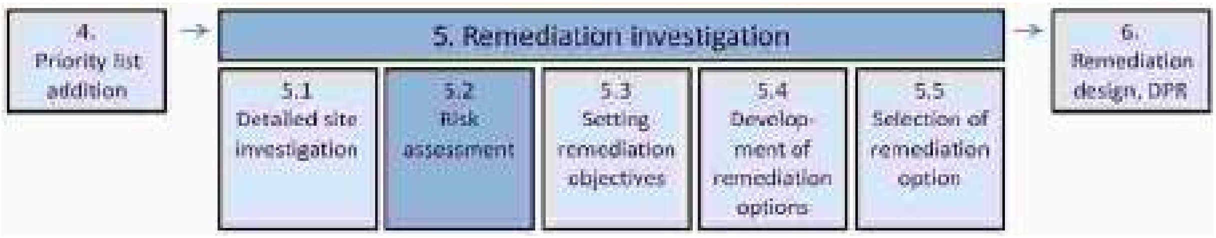
Step 5: Remediation investigation

Task 5.2: Risk Assessment

5.2.1 Introduction to and scope of task 5.2

General description and connection to other Steps and Tasks
Task 5.2, “Risk Assessment”, concerns the assessment of the risks caused by the contamination as investigated during Task 5.1 Detailed site investigation. Risk assessment is the process of identifying, assessing and evaluating the risks that may be associated with a threat to human health and/or the environment at a contaminated site. The result of the risk assessment provides information to determine if remediation is warranted and if so, to provide input for the selection of remediation objectives and the development of remediation options. This way, the remediation objectives established in Task 5.3 and the remediation options developed in Task 5.4 are aligned with the identified risks.

The figure below illustrates how this Task 5.2 is connected to the preceding and following Steps and Tasks in the sequence of site assessment and remediation.



Activities
The following activities are performed in Task 5.2:

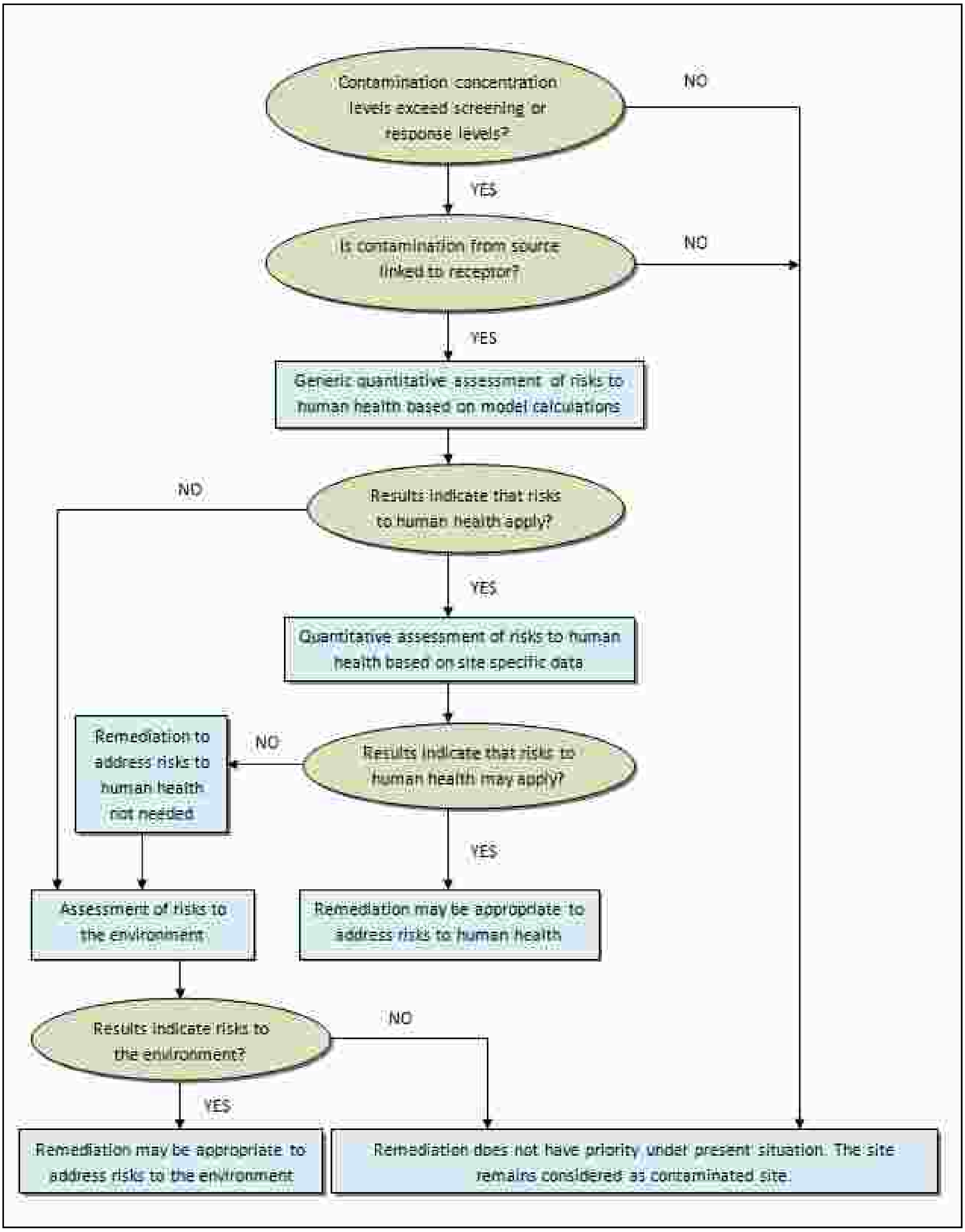
1. Assess contaminant concentration levels;
2. Identify applicable source-pathway-receptor-combinations for human health;
3. Perform a generic quantitative risk assessment for human health;
4. If necessary, perform a more detailed quantitative risk assessment for human health;
5. If necessary, perform a risk assessment for the environment.

This sequence of activities provides a tiered approach to achieve a sound and efficient decision on whether the contamination leads to risks for human health and/or the environment in the current situation at the site. This is visualised in figure I-5.2.1

Responsible Parties
The activities in this step are typically carried out by technical specialists within the competent authority for the remediation process, or the appointed consultant.

The team involved should demonstrate in-depth knowledge and experience in the risk assessment of contaminated sites. For complex risk assessment studies research institutes may be involved.

Figure I-5.2.1 Flowchart tiered approach for risk assessment



5.2.2 Guidance for performing the activities of Task 5.2

This section presents concise guidance for the performance of the activities within Task 5.2. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Assess contaminant concentration levels

The aim of this activity is to draw a preliminary conclusion on whether the pollution may cause risks. This is done by comparing the contaminant concentration levels described in previous investigation reports with general key values for soil, sediment and groundwater quality (refer *Screening and Response levels, Volume II-2.1-b*). This activity may have been performed during the preliminary or detailed site investigation. In that case the results of the activity should have been incorporated in the respective site investigation reports.

In cases where the contaminant concentration levels are below the Screening levels it can be concluded that there are no relevant risks to human health or the environment. Based on this the competent authority may decide to remove the site from the Priority list of contaminated sites and determine as investigated site.

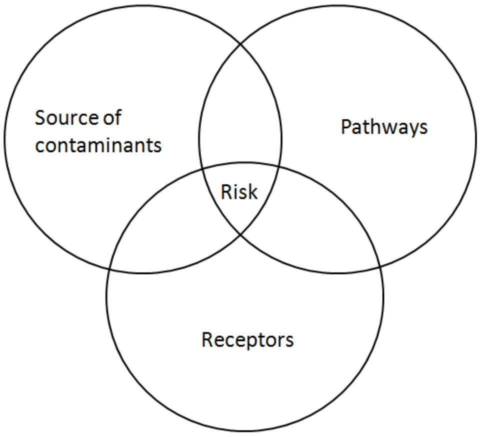
In case contaminant concentration levels exceed the Response levels there may be risks involved. This means further risk assessment is required, which would typically commence by proceeding to activity 2.

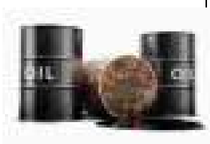
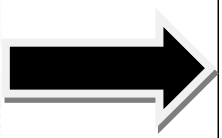
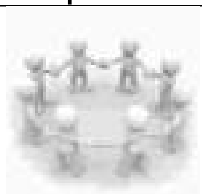
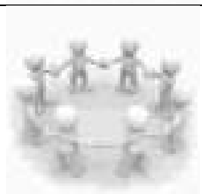
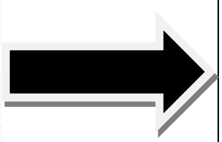
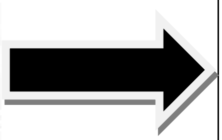
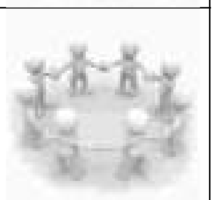
Activity 2 – Identify applicable source-pathway-receptor combinations for human health

The occurrence of risks depends on three components: source, pathway and receptor. It is important to note that all three of these components must be present for risks to occur. This is illustrated in figure I-5.2.2. In a situation where for example high concentrations of chemicals occur in a source but there are no receptors that can come into contact with these chemicals then risks cannot occur. It has to be emphasized that in future the situation of the site may change and contact with chemicals may become a possibility.

- Source: the location from which a contaminant(s) has entered or may enter a physical system. A primary source, such as a location at which drums have leaked onto surface soils, may produce a secondary source, such as contaminated soils;. Sources may hence be primary or secondary
- Pathway: the course through which contaminants in the environment may move away from the source(s) to potential environmental receptors.
- Receptor: humans and other living organisms potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along contaminant migration pathways.

Figure I-5.2.2-a and b   Risks occur only if source, pathway and receptor are all present (demonstrated in two different ways)



Source	Pathway	Receptor	Risks?
			Risk from this source may apply for this receptor
			
			No risk from this source for this receptor
			

Therefore, to assess whether the contamination may pose risks to human health and/or the environment it should first be established if all three components are present. This is typically done by identifying which combinations occur of the source from which contaminants are released, the transport medium that carries the contaminants to the receptors and the receptors that may come into contact with the contaminants. This is the qualitative phase of the risk assessment process. A diagram may be used to visualise the combinations that occur at the site. Such a diagram clearly shows the exposure routes (refer *Tools for risk assessment, Volume III-5.2-i* for an example). The resulting diagram serves as a basis for the quantification of risks, as in that phase attention should be paid only to the potential source-pathway-receptor-combinations.

The source-pathway-receptor-combinations applicable to assess human risks depend on the structure and use of the contaminated site and its vicinity. The source-pathway-receptor combinations resulting in the most threatening exposure are:

- Contact of human with contamination through:
  - Direct contact with contaminated soil or groundwater (ingestion of soil or groundwater, inhalation of dust, dermal uptake of contaminants from the soil or from the groundwater) (figure I.5.2.3 below);
  - Ingestion of cultivated crops grown on the contaminated site;
  - Ingestion of fish from contaminated water;
  - Ingestion of drinking water from contaminated groundwater;
  - Inhalation of indoor air influenced by contaminated soil or groundwater.
- For ecology:
  - Uptake of contaminants from the top layer of the soil;
  - The leaching of contaminants to surface water.

Figure I.5.2.3-a and b Examples of direct contact of human with contaminated soil and groundwater

<u>Activity 3 – Perform a generic quantitative risk assessment for human health</u>

In case relevant source-pathway-receptor-combinations are identified a generic quantitative risk assessment for human may be carried out in order to quantify the risks the contamination may pose to human health. This is done by applying a generic risk assessment model. Internationally, different generic models for risk assessment are applied. These models show varying degrees of complexity in investigation and many are related specifically to the local legislative requirements. Each has a slightly different emphasis, depending on the focus of the agency and the types of sites expected to be encountered. Examples of risk assessment models are presented in *Volume III-5.2-i Tools for risk assessment*.

For effective use of any of these models data from the detailed site investigation report are required as input. Otherwise, for this activity no specific measurements are performed.

Most of the models calculate the intake of contamination by humans, expressed in mg contaminant per kg bodyweight. To determine whether or not there are risks to human health, the intake of a contaminant needs to be compared to a certain critical exposure value. When this level is exceeded for one or more of the contaminants this implies the presence of an unacceptable risk for human health.

In case it is concluded that the results from this activity satisfactorily express the risks in the given situation the assessment of risks for human health may be concluded. However, most of the available generic models for risk assessment are 'conservative'. This means that the default parameters used and the calculation of the level of risk will tend to overestimate this level. This is an important drawback, because it should be avoided that model calculations indicate that there are no risks while in practice there are actual risks. Due to this conservative approach the model calculations may indicate risks to human health where in the actual situation there are no risks. If it is suspected that this situation occurs, the risk assessment can be refined by performing activity 4. Typically, the results of the risk assessment so far are discussed with the competent authority, to reach a shared conclusion on whether to perform Activity 4 or not.

Stakeholder	Interview objective	Level
Competent authority	provide information and discuss conclusion	level of competent authority

Activity 4 – Perform a more detailed quantitative risk assessment for human health

In this activity more detailed information is collected for a more refined site specific risk assessment. If so desired, this activity can also be carried out to support the result of the generic model calculation.

The site specific risk assessment is carried out by collecting additional relevant information, e.g. by measuring the concentration of substances in contact media such as indoor or outdoor air samples, drinking water samples, crop samples or dust samples. Care should be taken to measure in these samples the same contaminants that have been identified in the soil samples during the site investigation. Subsequently, the risk assessment model calculated concentrations in e.g. indoor air or crops can be replaced by measured concentrations. Because the results of these measurements are more reliable than the results of modelling, a final site specific conclusion based on measurements in contact media can be drawn.

Activity 5 – Perform a risk assessment for the environment

If the contaminated site is situated in an area with high ecological value (land use: forests and other natural area), it may be required to assess the risks the contamination poses to the environment. The decision on whether this requirement applies to the site at hand or not is usually discussed with the competent authority.

Stakeholder	Interview objective	Level
Competent authority	provide information and discuss conclusion	level of competent authority

For such an assessment a tiered approach is also applicable. An example of an available method is the Soil Quality Triad. This method of Dutch origin combines the results of three types of assessment: chemical analysis, toxicity tests and ecological field surveys. Based on integration of the results of these three surveys the assessment provides a sound basis for a decision on remediation.

5.2.3 Task 5.2 output

The output of Task 5.2 provides clear information whether the contamination causes unacceptable risks for human health and/or the environment or not. If risks are present, the assessment provides insight which part of the contamination causes risks and by which pathways. This is useful information for the development of remediation options.

The result of extensive detailed risk study might indicate there are no unacceptable risks involved for current and future land use. In that case the notification as contaminated site may be reconsidered. If risk assessment indicates there are no unacceptable risks for current land use but there may be unacceptable risks after change of land use the priority for remediation measures may be reconsidered and monitoring of the land use may be implemented.

The checklist of elements for a risk assessment report is presented in *Volume II-5.2-a.* The competent authority charged with reviewing the risk assessment report may refer to this checklist. First, it needs to be determined which of these elements are relevant for the situation at hand. The competent authority may then proceed by assessing whether the report contains all these relevant elements. Data in the report should be complete and presented clearly. Most important, the report should show that the data and other information underpin the conclusions.

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Step 5 Remediation investigation
Task 5.3 Setting remediation objectives and requirements

Step 5: Remediation investigation

Task 5.3: Setting remediation objectives and requirements

5.3.1 Introduction to and scope of Task 5.3

General description and connection to other Steps and Tasks
Task 5.3 is part of Step 5 Remediation Investigation and concerns the setting of remediation objectives and remediation requirements for the identified contaminated site.

Task 5.3 commences with the output from Task 5.2 which outlines where at the site contamination is resulting in unacceptable risks for the current or future site use. It ends with a clear focus on the remediation objectives and requirements including the considerations which have lead to them. This also forms the starting point for the subsequent Task 5.4.
The figure below shows how this Task is connected to the preceding and following Steps and Tasks within the sequence of site assessment and remediation.

Activities
The following activities are performed in Task 5.3:
1) Establish remediation objectives;
2) Establish remediation requirements.

Responsible Parties
The activities in this Task are typically carried out by technical specialists within the competent authority for the remediation process, or the appointed consultant.

The team involved requires knowledge of the remediation regulation and should demonstrate in-depth knowledge and experience of the environmental fate, transport and degradation characteristics of contaminants (e.g. mobility, biodegradability). In addition, the team should have experience of the performance of remediation techniques and their physical, hydrological and social impacts. Cooperation with the site owner (non-orphan site) and the competent authorities (orphan sites) would be appropriate, in view of the potentially considerable implications of decisions made at this stage.

A review and approval by the competent authorities is required before moving to the next task 5.4 ‘Development of Remediation Options’.

5.3.2 Guidance for performing the activities of Task 5.3

This section presents concise guidance for the performance of the activities within Task 5.3. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Establish remediation objectives

General principle governing this decision
The main aim of remediation of contaminated sites is to eliminate unacceptable risks of harm to human health and the environment or to reduce the risks to an acceptable level.

To eliminate the unacceptable risks complete removal or treatment of the contamination source is not always required. Often, the risk of actual exposure to high contaminant concentrations is limited, e.g. because the site is capped or because the contaminated material is above groundwater level. Therefore, the fundamental decision is to establish whether a complete restoration to pristine conditions is appropriate, or if an alternative approach is warranted. This approach would need to satisfactorily address the risks and would take into consideration the intended site use, costs, liability or long term obligations. This Section discusses the main considerations for this decision.

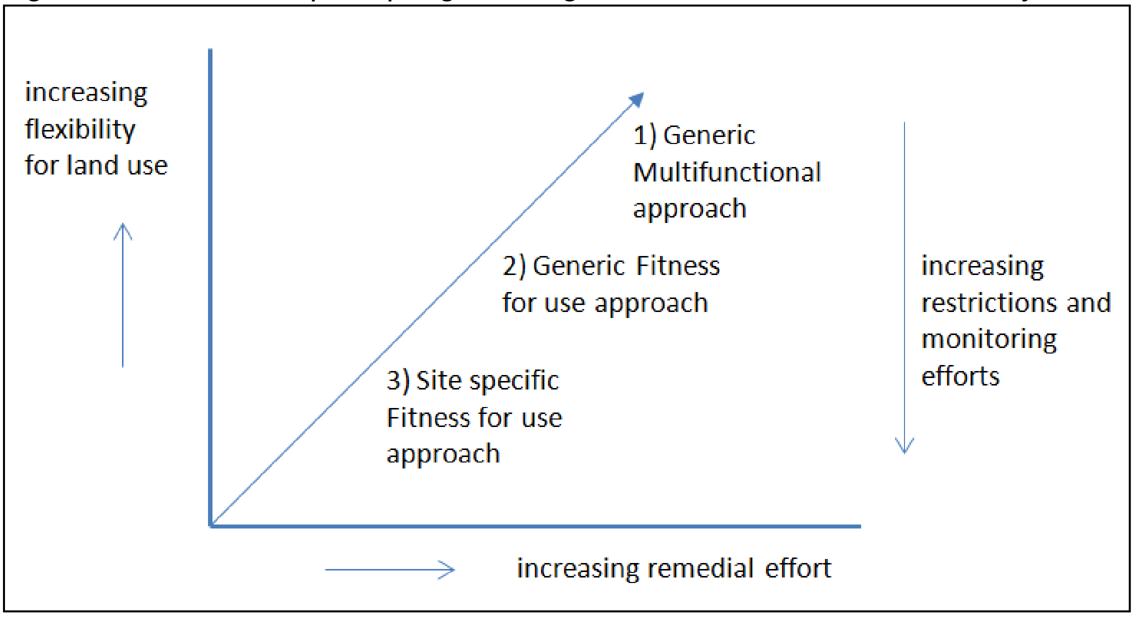
The decision on the remediation objectives is primarily governed by the general principle that more remediation effort results in increased land use flexibility/possibilities and less monitoring or maintenance requirements as illustrated in figure I-5.3.1.

The objective of complete restoration of a site to pristine conditions renders the site fit for all forms of land use. This is termed ‘multifunctional’, and requires a generic multifunctional approach, which will in practice mean complete removal of all contamination.

Alternatively, should complete restoration of the site be either not possible or desirable, the strategic decision will be to restore the site to such a level that is will be fit for the current or intended future use. This requires either a generic fitness for use or a site specific fitness for use approach. This approach can, for example, involve the blocking of exposure pathways or removal of affected receptors instead of removal of the source.

A generic multifunctional approach renders the site fit for all use without any post remediation constraints or liabilities. However, this approach typically involves high initial costs and sometimes high environmental impact regarding use of energy and materials and other negative effects. A fitness for use or cost effective approach is typically characterized by lower initial costs, but may result, depending on the situation, in considerable maintenance costs and site use restrictions.

Figure I.5.3.1General principle governing the decision on remediation objectives



In Box I-5.3.1 the major considerations which influence the selection of remediation objectives. For additional information, a.o. on international practices refer to *Background information for setting Remediation objectives, Volume II-5.3-a*.

Box I-5.3.1 Considerations for complete removal versus fitness for use

- Small site area and small volumes of contaminated material: complete removal or clean-up to background or target levels is relatively straightforward at such sites, and at relatively low cost.
- Liabilities: if the contamination is completely removed, there will be no potential future liabilities. This approach presents a high degree of confidence against any future legal claims or discussions regarding the presence of contamination. For this reason private companies may select this approach.
- Technical complexity and physical constraints, e.g. depth of the contaminants, groundwater depth, subsurface infrastructure, sensitive structures or the presence of other contaminants, may preclude complete removal;
- Long-term constraints and financial commitments, such as on-going monitoring and maintenance costs, and site use restrictions may not be appropriate.

If a fitness for use approach is selected, risk-based generic or site specific remediation target levels may be selected. The choice between either site specific or generic remediation target levels depends on cost-benefit considerations.

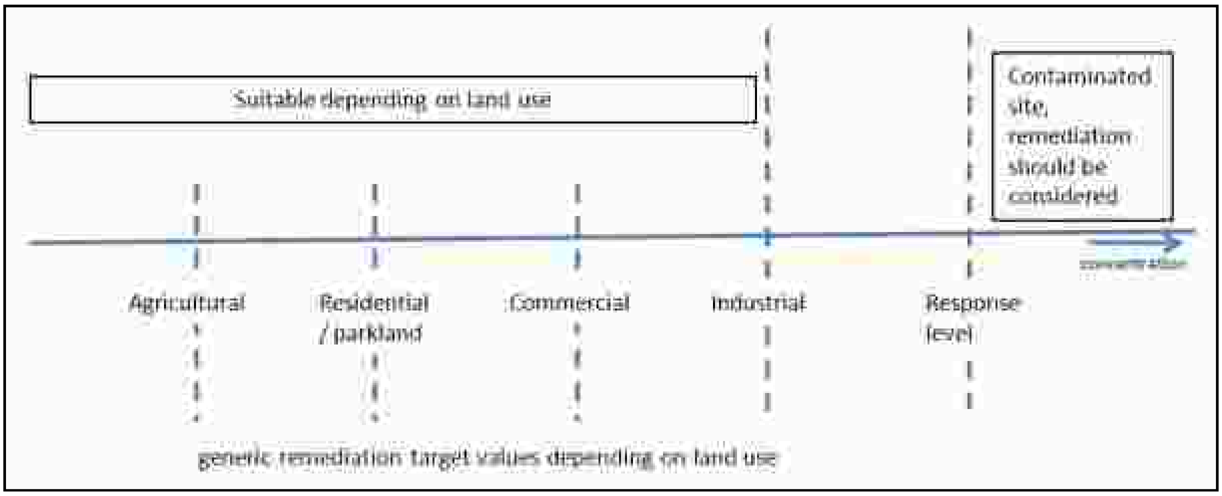
A generic target level will provide more future site use flexibility/possibilities. This because the target level is fit for a generic set of possible site uses within a particular land use category. Categories of land use are listed in Table I-5.3.1 below.

Table I-5.3.1 Categories of land use

Land use	Category of land use in regard of the generic remediation target level for soil and sediment
Agricultural land Kitchen garden Forests and other natural area	Agricultural
Habitation settlements (residential, school, kindergarten/playground, recreational park)	Residential / park land
Commercial	Commercial (relatively accessible sites)
Industrial Infrastructure (e.g. roads, parking, railway, subsurface cables and pipes) Waste land	Industrial (limited accessible sites)
Water bodies	For sediment depending on land use of the surrounding area
Mixed (to be specified for each use)	Select the most vulnerable of land use
Other (to be specified for each use)	Select the most vulnerable of land use

The decision on whether or not remediation is to be implemented is based on the assessment of contaminant concentration levels in soil (or sediment) and groundwater against the Response level. Remediation should result in a situation where the (lower) screening levels for the current or intended future land use are met. Figure I.5.3.2 below schematically shows the relation between the response levels on the one hand and the different screening levels on the other.

Figure I.5.3.2 Schematic overview of generic remediation target levels for soil and sediment and position relative to response levels



For the Screening levels the Canadian soil quality guidelines are applied. These generic soil quality guidelines present a level of negligible risk (soil remediated to these levels will represent a healthy, functioning ecosystem capable of sustaining the current and future uses of the site by ecological receptors and humans, including uses of groundwater). When the site investigation shows these levels are not exceeded no further investigation is required. These levels are below the Response levels which are based on the Dutch intervention values.

The Screening levels for soil and sediment are presented for four categories of land use: 1) agricultural, 2) residential/parkland, 3) commercial and 4) industrial land use. Each of these forms of land use represents a different impact of (contaminated) soil to humans and to the environment.
For groundwater the Indian Standards for Drinking Water are applied as generic target levels for remediation. If compounds are not addressed by these standards the generic remediation target levels are taken from Guidelines for Canadian Drinking Water Quality. Where Canadian values are also unavailable the levels from WHO Guidelines for Drinking water apply.

The Screening levels for the quality of soil, sediment, groundwater and surface water are listed in *Volume II-2.1-b*. It is proposed to align the generic remediation target levels with these site screening levels. In this way these levels can be regarded as remediation target levels within the framework of a generic fitness for use threat reduction. For comparison, the table also lists the response levels.

Application of generic remediation target levels is carried out as follows:

1) Determine the current or future use of the site and, if relevant, of groundwater and relate this use to one of the land use categories in Table I.5.3.1;
2) Determine remediation target values for soil (or sediment) and, if relevant, for groundwater by referring to the levels applicable to the relevant land use category in *Volume II-2.1-b Screening and Response levels*;
3) Establish whether specific conditions apply which may influence remediation target levels.

A site specific target level is tailor made for the site specific current or intended future site use (e.g. in case there are significant ecological concerns because of sensitive habitats for wildlife or endangered species). In case of special site characteristics (e.g. in case of a very large contaminated site which will result in very high remediation costs) or in case there are certain data gaps it may be recommended to develop site specific target levels as well. This offers cost effective remediation options, but minimizes site use flexibility/possibilities, because it is developed specifically for the use of the site at hand. Another advantage of using site specific target levels is that site specific background concentrations of naturally occurring substances can be taken into account (refer Box I-5.3.2).

Box I-5.3.2 Contaminants of natural origin

High background levels of naturally occurring substances may be present in soil or groundwater. For example, arsenic is a commonly occurring groundwater contaminant associated with particular geological formations. Remediating such contamination would be impracticable as natural replenishment of the contaminant would be inevitable. This underlines the importance to determine whether a contamination has been caused by human influence.

Cost benefit analysis is typically applied in cases of groundwater contamination. The costs associated with remediation of extensive plumes of dissolved contaminants within groundwater bodies can be extremely high without a clearly identified endpoint. The cost / benefit approach identifies a site specific remediation goal which optimises the remediation costs to reduce contaminant concentrations. Otherwise, the further, incremental reduction in contaminant concentrations achieved by additional effort can become significantly disproportionate to the cost involved.

The decision for such an approach will depend on the local circumstances. For example, if groundwater is the only source of drinking water and it is directly consumed after abstraction, cost / benefit analysis may be considered.

Activity 2 – Establish remediation requirements

Remediation requirements comprise the physical, functional or management tasks and the performance criteria which enable an effective remediation option.
Typical requirements include:

- Plans for redevelopment of site or the surrounding area may influence which remediation options may be developed.
- The degree to which the remediation option is robust (refer explanation in Box I-5.3.3 below).
- The extent to which management is necessary to implement site use restrictions, to monitor groundwater plumes, or the maintenance of pump and treat plant etc.
- Commercial and social aspects concerning property value, employment opportunities and the views of local stakeholders.

The requirements identified define the criteria which are incorporated into the remediation options appraisal (refer *Checklist Criteria for comparison and appraisal of remediation options, Volume II-5.5-a)*.

Box I-5.3.3 Explanation of robust (solid) remediation

Robust (solid) remediation options are able to adapt to changes in site or soil conditions without endangering the performance of the option. Examples of robust options include:

- A cover layer designed to provide intrinsic protection from unauthorized excavation and construction activities. This can be achieved by incorporating a durable layer within the clean cover system which is very hard to dig through without heavy machines. In case of sites influenced by occasional flooding a cover layer may be not a robust remediation due to vulnerability for erosion;
- Systems monitoring the spreading of groundwater plumes typically incorporate monitoring wells which are used for periodical sampling. In case the system is sensitive to changes in groundwater flow direction, or is situated in an area with periodical changes in groundwater use, the monitoring system can be designed to accommodate the abstraction of groundwater as well. In addition, automated sensors can be used for continuous monitoring of the groundwater flow;
- In urban build-up areas source removal by excavation and off-site disposal is generally inappropriate. In such cases a clean cover layer can be installed which can be designed for the specific site use. A uniform and deep cover layer would facilitate such future activities without the continuous risk of accidentally disturbing contamination below the cover layer.

5.3.3 Task 5.3 output

The output of Task 5.3 is a detailed description of the remediation objectives, the target levels to be achieved and performance requirements for the remediation of the site. This description should include the rationale leading to the resulting remediation objectives and performance requirements.

The results of Task 5.3 will largely determine which remediation options may be developed. Therefore, the output should be submitted to the competent authorities for review, even if a formal decision is not required.
During the following Task 5.4 remediation options are developed and the most favourable option is identified during Task 5.5. During these Tasks 5.4 and 5.5 the conclusion may be drawn that the performance requirements set in Task 5.3 are too stringent to meet. Therefore, it may be necessary to anticipate this situation by going through all these Tasks in an iterative way, combining development of remediation objectives, remediation requirements and remediation options.

Volume I

Step 5 Remediation investigation

Task 5.4 Development of remediation options

Step 5: Remediation investigation

Task 5.4 Development of remediation options

5.4.1 Introduction to and scope of task 5.4

General description and connection to other Steps and Tasks
Task 5.4 is part of Step 5 Remediation Investigation and concerns the development and suitability assessment of remediation options that may be appropriate to meet the remediation objectives established in Task 5.3. A remediation option is typically a combination of one or more remediation techniques that will enable to achieve the remediation objectives.

Task 5.4 commences with the assessment of the remediation objectives established in the preceding Task 5.3. It ends with the presentation of suitable remediation options from which one will be selected in the subsequent Task 5.5.
The figure below shows how this Task is connected to preceding and following Steps and Tasks within the sequence of site assessment and remediation.

Activities
The following activities are performed in Task 5.4:
1) Assess the remediation objectives and requirements;
2) Identify constraints to remediation;
3) Identify applicable remediation techniques;
4) Develop applicable remediation options.

Responsible parties
The activities in this Task are typically carried out by technical specialists within the competent authority for the remediation process, or the appointed consultant.

The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of remediation techniques and the physical, hydrological and social impact of techniques.

5.4.2 Guidance for performing the Activities of Task 5.4

This section presents concise guidance for the performance of the activities within Task 5.4. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Assess the remediation objectives and requirements
All remediation options considered in Task 5.4 should be able to meet the remediation objectives and requirements. Therefore, the first activity is to carefully assess the objectives and requirements which are to be met, in order to identify performance criteria relevant for consideration in the remediation options appraisal.
An example of these criteria is the target level for contaminating substances in soil and in groundwater.

Activity 2 – Identify constraints to remediation
In addition to the remediation objectives and requirements there may also be constraints imposed on the remediation.

They do not have an impact on the remediation objectives or requirements, but may affect how these objectives can be achieved:

- They may restrict or limit the range of applicable remediation techniques;
- They may determine the technical specifications for the techniques.

Constraints comprise technical and non-technical issues. Some examples of constraints are listed in Box I-5.4.1below.

Potential constraints for remediation may be identified by the party or the parties responsible for the site, for example the site owner or developer or, in the case of orphan sites, the competent authority. Constraints may also arise from consultations with other stakeholders, e.g. the municipality regarding spatial planning of the surrounding area or the local community. As constraints can have considerable influence on the remediation, the performing agent should consult all stakeholders who may raise an issue which could constrain the proposed remediation.

If a large number of stakeholders is involved the list of constraints may grow to a considerable extent. At a later stage this may lead to the conclusion that they impose a prohibitive financial burden on the remediation or that conflicting interests may need to be dealt with. Therefore, the activities in this Task may need repeated reviews during later activities. When a certain constraint is subject to change the stakeholder linked to that specific constraint should always be consulted.

Box I-5.4.1 Examples of remediation constraints

Soil remediation is often performed as part of redevelopment of an area. This intention will typically have been established in Task 5.3, along with the remediation target levels (concentrations of contamination in soil, sediment, groundwater or surface water) to be achieved. In most cases, the remediation process would be aligned with the redevelopment, leading to constraints such as the following:

- The redevelopment will require the site to be available for the intended future use at a specific date. The remediation planning should therefore aim to be completed by that date. This time constraint would rule out remediation options which would require a lengthier period of time to complete.
- In case post remediation measures have to be implemented at the redeveloped site, these measures need to fit in the future site use. They should not give rise to impacts on site users from noise (e.g. a groundwater treatment plant) and should not need to be replaced on a regular basis (e.g. a groundwater pumping system).

Physical restrictions such as nearby structures that must not be destabilised, or services and communications that must not be interrupted, e.g. railroads or power lines:

- Contaminated material may be present at a site with historic or vulnerable buildings which may be afforded protection. Where contamination source excavation and removal is proposed, excavation techniques should be considered carefully, because such techniques may cause damage to the building. Where this is proposed, additional measures to protect the building should be examined. However, should these measures then turn out to be too expensive or too high risk, these techniques for source removal should be rejected.
- When buildings or structures are located near the remediation site, the groundwater level should not be lowered too much, to prevent destabilisation of foundations leading to their potential settlement. This constraint would limit the potential capacity of the proposed remediation technique, e.g. the abstraction rate and zone of influence of a pump and treat system.

During the implementation of remediation certain activities may cause nuisance e.g. noise, the spreading of dust or the temporary closure of major infrastructure. For sites situated in urban areas specific limits may be imposed on the degree to which this nuisance is acceptable (restricted operating hours or the use of less noisy equipment). It may also lead to the selection of a different access route to the site, a different type of pump and treat system or even to the use of a different type of remediation technique etc.

Other examples of constraints to remediation are:

- Specific issues raised by interested parties such as the future owner, or stakeholder expectations etc;
- Corporate environmental policies:
- A requirement to avoid long term costs;
- A requirement to optimize sustainability within each of the options;
- A requirement not to affect groundwater wells during the implementation of the remediation activities;
- Abundant rainfall or evaporation may influence groundwater and surface water levels and may influence certain remediation techniques.

Activity 3 – Identify applicable remediation techniques

A remediation option typically consists of a combination of remediation techniques tailored to meet specific site remediation objectives, requirements and constraints. To develop an option, the performing agent starts by identifying techniques applicable to the given situation from a list of all possible techniques. The *Overview of remediation techniques and Menu of options, Volume III-5.4-i* provide detailed information on techniques.

Applicable techniques are typically identified through a process of elimination, i.e. dismissal of techniques deemed unsuitable for the specific situation. This identification is based on the objectives and requirements developed in Task 5.3 and constraints identified in Activity 2 of this task. The data needed to perform this identification can be found in the applicability matrix and the generic and site specific characteristics and in the description of strengths and weaknesses, opportunities and threats of the remediation techniques (for both refer to *Volume III-5.4-i*).

Box I-5.4.2 Example: rejection of unsuitable remediation techniques

In this example, the remediation objective is the complete removal of all solid phase contamination. One of the principal constraints is the requirement that remediation must be completed within a period of a six months. This is because the redevelopment works programme requires the site to be available for the intended future use at that time. A number of the remediation techniques, or combinations thereof, will not meet this constraint and can, therefore, be rejected immediately. Only the identified techniques that can meet this constraint are considered further.

Potential techniques should not be hastily rejected as options that might have turned out to be applicable may not be given due consideration. For example: construction of a physical vertical groundwater barrier (cut-off wall) may result in the migration of polluted groundwater through the base of the confined contamination, and, therefore, this method may be rejected. However, this potential risk can be solved by combining the barrier with a groundwater extraction system. A combination of these two techniques may result in full confinement with the benefit of a low groundwater extraction flux, comprising a cost-effective solution.

An important note on the application of relatively unknown remediation techniques. A remediation technique must be technically proven before it can be applied with any guarantee of success. This means a newly developed, or otherwise unknown, remediation technique needs to be tested, at first under laboratory circumstances, but eventually also in the field, before it should be considered for application at any given site. The flowchart *Application newly developed remediation techniques, Volume II.5.4-a* provides more detailed guidance on this issue.

On completion of Activity 3 a list of potentially applicable remediation techniques should be recorded as the activity output. This should preferably also include technical specifications that should be taken into account (e.g. to meet the remediation requirements) and any possible data gaps and uncertainty to be addressed by additional detailed site investigation.

Activity 4 – Develop applicable remediation options

The implementation of a single remediation technique is typically insufficient to meet the identified remediation objectives, requirements and constraints. Hence, often two or more remediation techniques are combined in a remediation option.

The process of combining remediation techniques to form a remediation option is the scope of this activity. The result will be a number of potential remediation options each covering the whole range of remediation objectives.

The number of remediation options developed is typically three or four, depending on the site-specific remediation objectives, requirements and constraints. For each remediation option listed, all criteria on which the option will be evaluated during Task 5.5 should be described and illustrated. An overview of these criteria can be found in the *Checklist Criteria for comparison and appraisal of remediation options, Volume II-5.5-a.*

Whilst there is no established process that should be followed when developing the remediation options, an iterative procedure is recommended (refer Box I-5.4.3 for examples).

Box I-5.4.3 Example: reasons for iterative option development

At some point in the process of option development issues may arise which need further investigation before the option development can be finalised. Examples of such issues are:

- complete delineation of the contaminated area;
- assessment of biodegradation rates in the subsoil in order to establish whether biodegradability of a contaminated groundwater plume is a possible option;
- assessment of social impacts of the options, e.g. when an option implies the capping of a waste dumping site it may mean this will have a negative impact on employment of communities using the site for economical purposes.

In contrast some technical details can be dealt with during the Remediation design (Step 6). An example of this would be the measurement of soil permeability, to be assessed in Step 6 in order to design the spacing of groundwater abstraction wells.

Recommendations and suggestions are provided below to enable the performing agent in his task to develop the remediation options.

Best practice
The Menu of remediation options (refer *Volume III-5.4-i*) offers an overview of best practice for all types of contaminated sites included in the Typology.

These options present a blueprint of preferred ('prioritized') options for remediation, i.e. the theoretically most appropriate remediation option for a variety of settings. Please note that the site- specific objectives, requirements and constraints may be conducive to develop further remediation options which are not featured in the Menu of remediation options.

The Menu of remediation options provides a first indication of potential remediation options that may be suitable for the situation at hand. For small and simple sites one or more best practice methods included in the menu may directly apply. In more complex situations the best practice overview will help the performing agent to make the first steps in the development of options.

Conceptual Site Model
While developing remediation options, the Conceptual Site Model (CSM), including the description of the sources, pathways and receptors (SPR's), is a useful tool (refer *Volume III-2.2-i*).
The CSM enables to understand [i] how the identified sources, pathways and receptors combine to present unacceptable risks, [ii] how the pollutant linkages are interconnected and [iii] how intervention in respect of either one or more of the sources, pathways or receptors by implementing the actual remediation techniques can reduce the risks.

Some examples of the CSM approach to designing a remediation scheme are provided below. The text also illustrates the benefits of remediation techniques which either have an impact on more than one of the sources, pathways and receptors, or benefit from a combination of techniques applied to individual sources, pathways and receptors:

- *Source Intervention* can reduce the risk of leaching of chemicals leading to groundwater contamination. Source intervention can also prevent the contact between receptors and the source and thus reduce the human health risks without the need for any further pathway or receptor controls. Examples of source intervention are removal of the contamination source (e.g. by excavation) or treatment in situ (e.g. by in-situ bioremediation).

- *Pathway Intervention* will reduce the risks of contaminant migration. An example of pathway intervention is interception of contaminated groundwater including treatment and discharge. An important issue in such a case is that where the source remains untreated, the interception including treatment and discharge will be necessary for a considerable time. However, when the interception of the pathway is combined with reduction of leaching from the source, a more effective remediation solution can be achieved. Another example of pathway intervention is capping of contaminated soil material by applying a capping layer. The use of a permeable capping layer will only reduce the direct human contact. However, in case the capping layer includes a impermeable element, the risks of spreading of contaminants are also reduced rendering the technique more efficient.

- *Receptor Intervention* mainly involves site use restrictions such as controlling an individual's exposure to pollutants by administrative means. These controls may comprise legal or contractual restrictions on access to, or use of, a garden or play ground. Other measures are focused on the protection or removal of the receptor and can be classified as temporary safety measures. Examples include re-housing, prohibiting access by fencing the site, preventing the use of groundwater for a potable source, e.g. by closing wells and providing water by alternative means (piping system, tanks, trucks).

Models for groundwater flow and mass transport

Models for groundwater flow and mass transport can be used to understand the hydrogeological regime and the pollutant mass transport mechanism. They provide detailed insight into aspects such as groundwater flow direction, plume migration and biodegradation rates. The use of such models allows an assessment of the remediation option suitability (e.g. aquifer permeability and applicability of groundwater control), effectiveness (e.g. volume of groundwater required for full plume capture, or reduction of plume size achieved by source removal) and configuration (e.g. number, depth and spacing of wells). They may also enable predicting any undesired consequences (e.g. effect of lowering of groundwater table on the construction of buildings and structures, or drought).

During this Task the model calculations are used just to get a basic insight into the above mentioned aspects. In Task 6, Remediation design, more thorough model calculations are sometimes required to derive the actual technical details needed for the design and implementation of the remediation works.

Practical rules of thumb

During the process of development of options the following practical and generic rules of thumb can be applied by the performing agent:

- Remediation techniques for removing the contamination load within a plume are most cost effective when combined with flux reduction from the source.
- The use of natural soil processes improves the efficiency of the remediation approach. For example: if time and space are available, the removal of groundwater contamination is more efficient if natural attenuation can be applied using the original inherent soil capabilities for biodegradation. This technique is slow but costs are low, even when natural conditions are enhanced by injecting the substratum with nutrients, oxygen etc.
- A combination of techniques can be efficient. For example, the removal of contaminants by excavating can be very efficient but only to the groundwater level. Below this depth, in situ extraction techniques are more cost-effective.
- If redevelopment or new construction works are planned on a site, a combined execution of the activities is usually attractive from various perspectives, e.g. costs, time, sustainability, and nuisance (refer Box I-5.4.4 below).

Box I-5.4.4 Practical information: redevelopment and remediation

Remediation of a contaminated site may be executed as an integrated part of a redevelopment plan for the area. This approach provides multiple opportunities to combine activities and to save on costs for both the remediation and redevelopment activities. Examples of combined activities are: [i] the excavation of contaminated soil can present an opportunity to utilise the resulting void as a basement or parking lot or [ii] the construction of new roads, pavements and building floor slabs can provide effective cover layers as an alternative to the construction of a cover system above contaminated soil or [iii] the excavated material may be reused or recycled into new raw materials e.g. organic matter from landfill sites or clayey material for brick manufacture.

When combining site remediation with site redevelopment it is advisable to develop the remediation options as an integrated part of the redevelopment plans. The consultant charged with the remediation investigation should cooperate with the site owner or site redeveloper and the engineers responsible for the design of the redevelopment. This cooperation should start at an early stage of the preparation phase providing maximum opportunities to combine both remediation and redevelopment activities. If started in an early stage this cooperation the land use plan can easily be adapted to the contamination situation. Often it is economically sensible e.g. to plan a parking lot on a former gasoline station instead of a playground or school garden. Even after decontamination of land people may not be willing to use that land for residential or other purposes. The possibility of using the land for setting up solar power generation system may be considered.

Cost estimates
For all remediation options costing is required. These costs may be estimated with an accuracy of plus or minus 20%. This is sufficient in order to compare the magnitude of costs of the different remediation options.

5.4.3 Task 5.4 output

The output of Task 5.4 is a set of applicable remediation options appropriate for the identified remediation objectives, requirements and preconditions. All options should be described in such a way that the selection of the most favourable option can be carried out in the next Task. The description of these options should include the technical specifications that should be taken into account (e.g. performance criteria to meet the requirements) or any data gaps and uncertainties requiring detailed site investigation.

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Step 5 Remediation investigation

Task 5.5 Selection remediation option

Step 5: Remediation investigation

Task 5.5: Selection remediation option

5.5.1 Introduction to and scope of Task 5.5

General description and connection to other steps and tasks
Task 5.5 is part of Step 5 Remediation Investigation and concerns the selection of the most applicable remediation option, i.e. the option best meeting all objectives, requirements and constraints established in the previous steps. The selection of this option is basically performed by matching the output of the preceding Task 5.4, i.e. the characteristics of several remediation options, with a standardized set of criteria. The most applicable remediation option is put forward to the competent authority for approval and provides input for the detailed engineering in a Remediation design plan (DPR) in the subsequent Step 6.

The figure below shows how this task is connected to the preceding and following steps and tasks within the sequence of site assessment and remediation.

Activities
The following activities are performed in Task 5.5:
1) Compare and appraise remediation options;
2) Consult with relevant stakeholders;
3) Prepare remediation investigation report, including stakeholder views;
4) Review and approval of remediation investigation report and select most favourable remediation option.

Responsible parties
The activities in this Task are typically carried out by technical specialists within the competent authority for the remediation process, or the appointed consultant.

The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of remediation techniques and the physical, hydrological and social impact of techniques.

A review by the competent authorities is required before moving to the next Step 6.

5.5.2 Guidance for performing the activities of Task 5.5

This section presents concise guidance for the performance of the activities within Task 5.5. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

<u>Activity 1 – Compare and appraise remediation options</u>

The previous Task 5.4 would have yielded a set of potentially applicable remediation options. In this Activity these options are compared and appraised, as a first move towards selection of the most favourable remediation option. The result of this Activity should enable stakeholder consultation (Activity 2), the writing of the Remediation investigation report (Activity 3) and the eventual selection of the most suitable remediation option (Activity 4).

Criteria to be included in the comparison and appraisal
The implementation of a remediation option can affect a wide variety of criteria like costs, site reuse potential and social impacts. The criteria that are expected to be affected by any of the remediation options should be used as criteria in the comparison and appraisal process. These may be selected from the comprehensive list of these criteria, presented in the *Checklist Criteria for comparison and appraisal of remediation options, Volume II-5.5-a*. They can also be located in the generic analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) of remediation techniques in *The Overview of remediation techniques and Menu of options, Volume III.5.4-i*.

Methods for comparison and appraisal
Following structured and comprehensive methods of comparison and appraisal of remediation options may be applied: descriptive methods, qualitative overview methods and quantitative overview methods. It is advised to apply one of these methods to obtain an overview of all characteristics of the remediation options and the differences among them. Such a method may also serve as a useful tool for the stakeholder consultation. Which method is most suitable depends on the number of remediation options and the complexity of these options. Examples of these types of methods are presented in *Volume III-5.5-i*.

Some practical issues to consider during the comparison and appraisal process:

- An ideal remediation option meets all criteria in a well balanced way. If this balance is not met with either of the remediation options the process could result in an unsatisfactory remediation option. In that case it may be necessary [i] to reconsider the objectives, requirements and constraints that should to be addressed by the remediation, [ii] to adjust the redevelopment plans, [iii] to fine tune the remediation options or to develop new options;
- In most cases the process of design, evaluation and selection will not end up with one single solution unconditionally acceptable for all parties. These steps therefore often are made in an iterative process. During this iterative process the design and conditions should gradually develop towards a most favourable option. Trans-

parency in all activities and close contact with the important stakeholders is a key element in this optimising process;
- The comparison and appraisal process may also yield recommendations that will need attention during the subsequent design and implementation of a remediation option. Examples of such recommendations are presented in Box I-5.5.1 below.

Box I-5.5.1 Examples of recommendations that warrant attention in further steps

- A most favourable remediation option can be based on a technique which has only been used in laboratory and never in field conditions. In this case this option can be indicated as the most favourable option only after a field test or pilot remediation has proven to give a certain level of results (for guidance on this see Volume II-5.4-a).
- The exact delineation of a contamination should be assessed in case complete removal is anticipated.
- In case remediation of a groundwater plume is selected as the most favourable remediation option, the biodegradability of the contaminants should be confirmed by additional site assessment first.

Activity 2 – Consult with relevant stakeholders

The implementation of remediation measures may considerably affect stakeholders. The issues involved can be of a social or environmental nature, like noise and dust production by remediation equipment or trucks, and even temporary relocation of inhabitants. Different remediation options can also have different economic effects, as they may e.g. affect the value of the property differently. Therefore the selection and design of the remediation option should be subject to stakeholder consultation. The results of the comparison and appraisal of remediation options (Activity 1) provides a solid basis to start stakeholder consultation as they discuss all relevant issues like level of risk reduction, technical risks, costs, sustainability, planning, post remediation site use potential.

Stakeholders with partial responsibilities in the remediation process and stakeholders that may have to deal with impacts of the remediation, should be involved during the selection of the remediation option. Example of these stakeholders are:
- Municipal Water board or Water Sanitation Department: water quality and, if applicable, use of the water supply and sewage system for a prolonged period of time;
- Municipality or Traffic Police Authorities Transport Department: traffic issues related to the remediation works;
- Urban Development Department or Industries Department: possibilities for post remediation site use and, if applicable, site use restrictions.

Stakeholders that should at least be informed on the backgrounds and results of the remediation option are for example site users, inhabitants and other people with primary dependence on the site use. In case of larger impact by the remediation it may serve well to involve these stakeholders already in the process of development of remediation options. This action can be vital in gathering support for the selected remediation option. In cases where resistance against the selected remediation option runs high, the selected option may be modified or even reconsidered. In higher profile situations, it may be useful to involve local elected representatives, local political party workers, media agencies and noted local personalities in the stakeholder consultations.

The stakeholder consultation should yield detailed information on their interests, which should be considered while selecting the most favourable remediation option and also later, during the remediation design and implementation of the remediation works. In some cases the stakeholder consultation may even lead to development of a new remediation option that may be included in the selection process.

Activity 3 – Prepare remediation investigation report, including stakeholder views

The process of comparing, appraising and eventually selecting remediation options should be well documented. This is done in a Remediation investigation report which presents the results of the detailed site investigation (Task 5.1), the risk assessment (Task 5.2), the setting of the remediation objectives and requirements (Task 5.3), the development of the remediation options (Task 5.4) and the comparison and appraisal of the remediation options, including the stakeholder consultation (Task 5.5) (refer *Checklist Remediation investigation report, Volume II-5.5-b.*

Activity 4 – Review and approval of remediation investigation report and selection of most favourable remediation option

Once the selection of the most applicable remediation is completed, the resulting option should be put forward to the competent authority for approval, ref. *Checklist review and approval Remediation investigation report, Volume II-5.5-c*.

The implementation of a remediation work may require approval by other authorities, e.g. the local water board in case of effluents into water bodies under their jurisdiction. In such cases, a sound and timely coordination among the involved authorities is crucial to prevent conflicting requirements.

5.5.3 Task 5.5 output

The output of this Task 5.5 is a selected most favourable remediation option, approved by the competent authority and preferably accepted by as many stakeholders as possible. The Remediation investigation report, in which the development, comparison, appraisal and selection process of this remediation option is documented, provides insight in the rationale for the eventual selection of the remediation option and for the actions to meet stakeholder interests. That report also includes a list of issues that need to be addressed during the following steps.

Based on this output a Remediation design plan (DPR) is prepared in the subsequent Step 6.

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Step 6 Remediation design, DPR

Step 6: Remediation design, DPR.

6.1 Introduction to and scope of Step 6

General description and connection to other steps
Step 6 concerns the design of the remediation and the development of a Detailed Project Report (DPR). In the DPR a detailed description of the remediation activities is provided. Part of this DPR is an estimation of the costs required for the funding of the project (Step 7). The DPR is providing the technical information to be elaborated in the bidding documents during the implementation of the remediation (Step 8). Step 6 starts with a summary of the remediation option selected at the end of the preceding Step 5 Remediation investigation. It ends with the presentation and approval of the DPR.

The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.

Activities
Within this Step the following activities are to be performed:

1) Design of the remediation: the technical system for the remediation will be presented. Detailed descriptions and drawings of the remediation measures will be reported.
2) Costing and planning of the remediation: all activities are summarized and a costing is provided for each of these activities (volumes, amounts and unit prices). A planning of activities is made indicating the time involved for the activities.
3) Environmental and social impact assessment and consultation of stakeholders

Responsible parties
The activities listed above will typically be performed by technical experts in the specialized agency or consultant charged with the remediation investigation.. The work should be supervised by a senior colleague. The team involved should have in-depth knowledge of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of remediation techniques and the physical, hydrological and social impact of techniques. The team involved should be able to interpret the technical information and link the necessary measures to costs involved. For various elements of the cost estimation information from authorities may be required.

6.2 Guidance for performing the activities of Step 6

This section presents concise guidance for the performance of the activities within Step 6. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 - Design of the remediation

The design of the remediation is meant to detail out the selected remediation option into separate, interconnected activities. The technical and organisational aspects of these activities and their environmental impact should be described in a Detailed Project Report or remediation design plan (DPR). For some of the technical measures it should be assessed if they are applicable for the specific site. Sometimes modelling can be required to assess the effects of the remedial measures e.g. the mass transport of contaminants when using ground water extraction or the degradation of contamination to predict the results of biological techniques.

The DPR is based on the selected remediation option during Task 5.5. If the remediation is combined with reconstruction or redevelopment activities at the site it should be described in detail how the activities of remediation and redevelopment are linked and which impact they have.

A stakeholder consultation is needed, both to inform the stakeholders on the intended remediation measures and to secure their support. The consultation may also yield information that can be useful in the final design of the remediation measures. Whether or not to include interviews with stakeholders at district, state and national level may involve the weighing of economic aspects. As a result, this may for the state and national levels only be applicable to large scale sites.

In case it is expected that the remediation will leave no residual contamination the decision on land use after remediation closure needs to be taken at this stage. In such cases therefore, the remediation design also needs to address this issue. This will then necessitate the involvement of a land use designation authority, which may take the shape of an interdepartmental committee with land use experts.

Stakeholder	Interview objective	Level
Site owner	exchange information, secure support	site
Site operator's health facility director	exchange information, secure support	site
Local businesses, residents and NGO's	exchange information, secure support	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	exchange information, secure support	local
In case it is expected the remediation will leave no residual contamination: Land Registration Office	discuss conclusion on land use post remediation	district / local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	exchange information, secure support	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	exchange information, secure support	national
Competent authority	provide information and discuss conclusion	level of competent authority

In the DPR the remediation objective is described as detailed as possible.
This allows for verification activities to be carried out, on the bases of which it is possible to conclude if the remediation objective is reached. For remediation techniques with can take a long period of time, the DPR should describe the management of the necessary monitoring activities to verify the progress of the remediation

If the remediation activities are causing waste, e.g. due to excavation, the Hazardous Waste Rules-2008 may apply with respect to transport, disposal or treatment of this material.

During the execution of remediation works unexpected issues will almost always occur. Examples include contaminated material in the subsoil which is present deeper than expected or permeability of the soil which is less than expected.
For the situation that the intended remediation objective cannot be achieved by the presented techniques, a fall-back scenario should be detailed and included in the DPR. This scenario provides technical measures by which the remediation objective eventually can be achieved.
Clear and measurable criteria for the success of the remediation should be part of the DPR. This allows the competent authority and the organization responsible for the remediation to make arrangements on the management of the remedial activities.

The remediation design plan / DPR has a standardized structure and content (refer *Checklist DPR including verification plan, Volume II-6-a*)

Activity 2 - Costing and planning of the remediation

All remediation activities are summarized and a costing is made for each of these activities. These activities do not only involve the technical measures of the remediation. The preparation of the work, including costs for demolishing building or replacement of inhabitants may be involved as well. The costs for management, supervision and verification of the remediation works should be included as well. The previous costs of investigation of the site and preparation of the remediation design may be summarized to the total of relevant costs.

The remediation may be combined with redevelopment of the site. It is important to distinguish costs for remediation and costs for redevelopment (e.g. a situation where an existing building should be demolished before remediation and reconstruction can take place. The demolition costs can be designated to the remediation as well as to the reconstruction). Depending on the financing parties of remediation and reconstruction this can be a major issue and point for discussion.

An overview of cost elements of a remediation is presented in the *Example format cost estimation remediation, Volume II-6-b*. The costing should include volumes, amounts and unit prices.

Some of the cost elements may be estimated quite accurately, some elements may be difficult to estimate (examples are provided in Box I-6.1). It may be useful to apply a bandwidth for elements which have large impact on the total costs.

Box I-6.1 Examples of uncertainties in cost estimates

- There may be uncertainties in the exact delineation of the contamination which can cause a deviation of the amount of contaminated material to be treated.
- The time necessary to achieve the desired results for an in-situ remediation.
- The starting point of the remediation project may not be known, which may have impact on the rate for disposal of excavated material on a TSDF.

Furthermore a planning of activities is made. In this planning the remediation activities as well as the verification activities are scheduled.

Activity 3 - Environmental and social impact assessment and stakeholder consultation

The remedial measures described in the DPR can have effects on the environment and the surroundings of the contaminated site. There may be negative effects from remedial measurements due to noise or dust by equipment used or by transport of contaminated material from the site.
During remediation the use of the site and surrounding area may be temporarily prohibited and this can have impact on communities using the site for economical purposes.

The environmental impact assessment should consider the effects of the remediation on the environment. It must include amongst others measures to minimise damage or nuisance caused by the remediation activities and measures to improve sustainability (e.g. reducing energy consumption). The social impact assessment must consider the effects of the remediation measures for the communities using the site. It should describe how communication is organised and what measures will be taken to minimise the effects of the remediation for the communities involved. It should also illustrate how the remediation of the site has positive effects on the possibilities for the owner and involved communities

All these effects are assessed in an Environmental and social impact assessment report (refer *Manual for environmental and social impact assessment for remediation of contaminated sites, Volume III-6-i*).

6.3 Step 6 output

The output of this step is a Detailed Project Report providing a clear and detailed description of the remediation system and the various techniques used. Furthermore a detailed planning and costing of the remedial measures are provided. Finally the report of an Environmental and social assessment is developed.
The competent authority has the responsibility for reviewing the DPR. If there is a necessity for involving stakeholders, the authority can share the report with these stakeholders. In that case maybe the costing can be regarded as non public element of the DPR.

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Step 7 DPR approval and financing

Step 7: DPR approval and financing

7.1 Introduction to and scope of Step 7

General description and connection to other steps
Step 7 concerns the approval of the remediation design in the DPR and the financing of the remediation works. Both these elements are required before getting into the actual process of remediation.
The figure below shows how this Step is connected to the preceding and subsequent Steps within the sequence of site assessment and remediation. The financing element of this Step 7 can start directly after notification of the contaminated site in Step 3.

Activities
Within this step a number of activities are to be performed. Most of these activities are on institutional, legal and financial aspects. For guidance on those activities we refer to the National Program for Remediation of Polluted Sites (Task 4 report, PWC Dec. 2015). Here, the guidance focuses on the one activity with technical/financial aspects:

1) Review and approval of DPR by the competent authority

Responsible Parties
Review is typically performed by senior staff members of the competent authority, in order to prepare the decision by the appropriate official. The team involved should be able to interpret the technical information of the DPR and link the necessary measures to costs involved.

7.2 Guidance for performing the activity of Step 7

This section presents concise guidance for the performance of the activity within Step 7. It is intended to enable the user to quickly gain an understanding of the necessary activity.

~~Activity 1 - Review and approval of DPR~~

The report of the remediation design / DPR will be reviewed by the competent authority. Points of attention for this review are provided in the *Checklist review and approval Detailed Project Report, Volume II-7-a:*

- The remediation objectives according to the selected remediation option (Task 5.5) should be met;
- The remediation should be technically well feasible;
- If the remediation is combined with reconstruction activities at the site the planning of the reconstruction does not have a negative impact on the remediation

measures (example: this could happen if in-situ remediation measures are applied and during the exploitation period of these measures groundwater extraction is applied to prepare reconstruction which can have a negative effect on the performance of the remediation);

- The results of the environmental and social impact assessment are acceptable and within regulatory permits. Where technically possible and economically reasonable additional measures will be applied to reduce negative impact of the remediation measures (examples: spraying of water in case of dust formation; temporary replacement of dwellings for residents during excavation);
- There are clear criteria to assess the progress and final result of the remediation (examples: permeability of a top clay layer used for containment of a site; concentration levels of pollutants and chemical properties of groundwater);
- The activities to verify the progress and results of the remediation are clearly described;
- Uncertainties which may have effect on the remediation result are indicated explicitly and the DPR provides scenarios and measures in case these uncertainties will occur.

7.3 Step 7 output

The output of this step is the approved DPR and certainty on budgets for the remediation and post remediation costs. Based on this the preparation of the remediation works can proceed.

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Step 8 Implementation of remediation

Task 8.1 Preparation and authorization

Step 8: Implementation of remediation

Task 8.1: Preparation and authorisation

8.1.1 Introduction to and scope of task 8.1

General description and connection to other Steps and Tasks

Step 8 concerns the implementation of the remediation of the established contaminated site. The remediation works have been described in the DPR (developed in Step 6) where the technical design of the selected remediation option (Task 5.5) is described in detail.

Step 8 is divided into three tasks: preparation and authorisation (Task 8.1), contracting (Task 8.2) and the execution and supervision and verification of the remediation (Task 8.3). Before the execution of the remediation works can start these remedial works should be authorised and necessary regulatory permits, licenses and/or consents should be met. This activity can take place parallel or in sequence with the contracting Step 8.2.

The figure below shows how this Task 8.1 is connected to the preceding and subsequent Steps and Tasks within the sequence of site assessment and remediation.

Activities
Within this Task 8.1 the following activities are to be performed:
1) Inventory of required permits.
2) Applying for the permits.

Responsible Parties
Generally, the organisation responsible for the remediation (authority, company or private party or person) will instruct the preparation of a project to ensure all regulatory obligations concerning the remediation works are met. This organisation can appoint a specialised third party, to take care for arranging these permits and licenses. The contractor may arrange these permits and licenses as a first step of the execution of the remediation works as well.
The team involved should be able to assess the information of the technical system and make conclusions on the required permits, licenses and consents. Knowledge of regional and local regulations is required as well.

8.1.2 Guidance for performing the activities of Task 8.1

This section presents concise guidance for the performance of the activities within Task 8.1. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 –Inventory of required permits

The required permits should be inventoried, refer *Checklist permits for remediation works, Volume II-8.1-a.* This is depending on the characteristics of the remediation design and the specific equipment the contractor will use during the execution of the remedial works, examples are provided in Box I-8.1.1 below.

Box I-8.1.1: Examples of activities for which the permits may be applicable

The remediation activities will have an impact on the contaminated site and its direct surroundings but the impact of the remediation may be more than that. Some examples:

- always transport of equipment to and from the site is involved in a remediation project;
- when removing of excavated material from the site there may be a large impact on the local transport network;
- at the site where treatment or disposal of the material takes place there may be a permanent installation which will require permits and licenses independently.

Activity 2 – Applying for the permits

The required permits, licenses and consents should be applied at the various governmental organisations. The municipal government and maybe different departments will surely be involved. Maybe the state government has to be consulted for specific regulations. Water boards may have to be involved if the remediation works have impact on ground water or surface water.

Providing detailed information of the impact and planning of the remediation works may be necessary during the application process. Part of this information may be obtained from the results of the Environmental and Social Impact Assessment, developed during Step 6 Remediation design, DPR.

8.1.3 Task 8.1 output

The output of this task 8.1 is a document including all obtained and signed permits, licenses and consents at this stage required for execution of the remediation works. May be the contractor will have to apply for permits just before the remediation works start in case specific equipment is involved.

This document with (copies of) all obtained permits, licenses and consents should always be readily available during the execution of the remediation works. In case the specific activities or specific equipment may be changed during the remedial works it is necessary to check if it is still possible to meet the obligations of the permits, licenses and consents.

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Step 8 Implementation of remediation

Task 8.2 Contracting

Step 8: Implementation of remediation

Task 8.2: Contracting

8.2.1 Introduction to and scope of task 8.2

General description and connection to other steps and tasks
Step 8 concerns the implementation of the remediation of the contaminated site. The remediation works are described in the DPR (developed in Step 6) wherein a technical design of the selected remediation option (Task 5.5) is elaborated.

Step 8 is divided into three tasks: preparation and authorisation (Task 8.1), contracting (Task 8.2) and the execution and supervision and verification of the remediation (Task 8.3).
The objective of Task 8.2 contracting is the selection and appointment of a contractor which can offer adequate results against acceptable costs.
Generally there are two main options for contracting: traditional contracting and design and build. Design and build implies the client directly employs a contractor to provide both design and implementation. With traditional contracting the client directly employs the designer for a DPR (Step 6) and the contractor for the remediation (Step 8) using separate contracts. In this section we will describe the traditional contracting process.

The contracting phase (Task 8.2) is carried out after the DPR approval and financing (Step 7) has been arranged and the authorization of the remediation by the competent authorities. The contracting is based on bid documents to be developed during this step. After the appointment of the works has taken place the execution of the remediation works can start.
The figure below shows how this Task 8.2 is connected to the preceding and subsequent Steps and Tasks within the sequence of site assessment and remediation.

Activities
Within this Task 8.2 the following activities are to be performed:
1) Preparation of bid document.
2) Selection and appointment of the contractor.

Responsible Parties
Generally, the client/organization responsible for the remediation (authority, company or private party or person) will instruct the development of bid documents and the contracting of a project. This organization can hire a consultant to develop the bid documents and to implement the contracting procedure. State and National Government needs to be involved throughout this Task.

The preparation of the bid documents and the contracting process should be supervised by senior colleagues with technical as well as financial background.

The team involved should demonstrate in-depth knowledge how to translate the remediation measures, described in the DPR into detailed technical activities. Knowledge of practical possibilities of technical solutions is necessary to develop these bid documents.
Furthermore experience with contracting procedures is required and capabilities on administrative, legal and financial aspects.

8.2.2 Guidance for performing the activities of Task 8.2

This section presents concise guidance for the performance of the activities within Task 8.2. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Preparation of bid document

In a bid document a very detailed technical description is provided of the remediation works as designed and reported in the DPR. It clearly defines the activities and measures and the results to be achieved by the contractor and the applicable criteria. It includes detailed description of activities, location of work, transport of equipment and traffic measures, building materials and waste material, temporary storage facilities at the site. In these descriptions reference is made to detailed drawings or pictures which have to be included (various scales; overviews and cross-sections; technical constructions). The bid document should describe possible preconditions for executing the work (e.g. accessibility of the site, security measures, daily routine time schedules).

Based on the bid document parties/contractors should be able to:
- develop a work plan of technical activities;
- include the health and safety measures for workers and people in neighboring area;
- identify the applicable equipment and project team (with possible subcontractors);
- calculate costs for an offer;
- develop a time schedule.

Despite of intensive investigation efforts during detailed site investigation there will always be some uncertainties regarding the exact delineation of the subsurface contamination or the behavior of substances in soil, sediment or groundwater. In the bid document clearly should be described how to deal with these uncertainties during the remediation works regarding the technical, legal and financial consequences.

Uncertainties are inevitable, due to the fact that the soil is largely invisible and any investigation is based on tests on a limited part of the total soil and groundwater volume. However, the uncertainties can be such that the investigation can be deemed insufficient. In such cases it may be considered to hold the Consultant liable for insufficient work. Therefore, this issue should be a point of attention in the drafting of the bid documents.

<u>Activity 2 – Selection and appointment of contractor</u>

The activities are depending on the chosen method of the tendering process. The tendering process is a method where the Indian Government, as well as Municipalities and most Corporations issue a procurement notice in newspapers, official government publications and over the internet for purchasing goods or services.
There are different tendering processes for different types of tenders.
The three types of tendering methods are:

1. Open Tendering;
2. Selective Tendering and
3. Negotiated Tendering.

Open Tendering Process
After the bid documents are finalised the tendering process comprises various stages.
The first stage includes the pre-qualification stage, where the client lays down criteria for qualifying for the work being tendered. This phase is considered as an important stage as it drastically cuts the number of bidders and selects only capable bidders.
The second stage is the tender invitation phase, where the client publishes or issues invitations to shortlisted bidders or to the public. This may not require media channels for communication.
The third stage is the tender clarifications and addenda phase, in which the client responds to the queries raised by the bidders in writing. It also engages possible issuance of tender addendums amending parts of the tender documents.
The fourth stage is the tender offer/bid submission phase where bids are presented in the form specified, mostly sealed envelopes and then there is the tender opening and the post tender clarification phase whereby the client goes through the tenders and seeks any clarification from the bidders.
The next stage is the award phase where the client issues an acceptance letter to the successful bidder who is usually, but not always, the lowest bidder and the last stage includes the formalisation of contract phase where the necessary documents are signed to formalize the agreement.

Selective tendering process
In a selective tendering process, the client selects only contractors that have delivered excellent results in previous similar tenders. This process includes three ways such as:

1. an advertisement may produce several interested contractors and suitable firms are selected to tender;
2. the consultants may contact those they would wish to put on an ad-hoc list and
3. many local authorities and national bodies keep approved lists of contractors in certain categories, such as work type and cost range.

Negotiated tendering process
In this process the client holds a one-to-one discussion with contractors to negotiate the terms of contract, as such tenders are mainly used for specialised projects like lift

systems, airport projects etc. at a larger level which includes a limited number of contractors who engage in these kind of projects from the industry.

In the Indian tendering scenario, frameworks are determined by guidelines set by the relevant international bodies including FIDIC (International Federation of Consulting Engineers for engineering) related tenders like computer tenders, civil work tenders and generators tenders.
However, the Indian Central and State Governments, Indian Municipalities and establishments such as Universities, the Military and Hospitals are governed by strict laws and only open competition bids are accepted.

It may be required to contract more than one party for the remediation works, an example is provided in Box I-8.2.1 below.

Box I-8.2.1 Example more than one party required to execute the work

It may be necessary to appoint more than one party to execute the work to be done. For instance in the situation where constructions present at the site have to be demolished anticipating the excavation of contaminated soil. Or the situation where a contractor executes an excavation work at the site and the excavated material is transported and treated by another contractor. For the supervision and verification of the remedial works the client always should appoint a third party which is independent from the contractor.

In the process of an open tendering for the remediation work there are various stages. The first stage includes the pre-qualification stage, where the client lays down criteria for qualifying for the work being tendered. This phase is considered as an important stage as it drastically cuts the number of bidders and selects only capable bidders.

Apart from financial and legal criteria there are several criteria possible to consider in the prequalification of a contractor. Some examples of these criteria are illustrated in Box I-8.2.2 below and more comprehensive in the *Checklist prequalification of contractors, Volume II-8.2-a*.

Box I-8.2.2 Examples of prequalification criteria

Company experience

- Track record of similar projects. Does the company or consortium have experience with the remediation techniques? Have these remediation works been implemented by the company in similar situations (type of contaminated site);
- Track record of projects with proven good project management skills;
- Company has appropriate health and safety policies and procedures in place;
- Pays attention to sustainability of certain aspects of the implementation (e.g. attention to save energy and to prevent nuisance);
- Quality management system.

Experience of Team and Team leader

- Good technical, management and communication skills;
- Capacity of the team is large enough to enable flexibility and to finalize the works according to the scheduled date;
- Awareness of policy and regulatory issues;
- Awareness of the need for verification;
- Ability to mobilize to the site in an acceptable period of time;
- Risk management approach to deal with uncertainties in the project.

8.2.3 Task 8.2 output

The output of this Task 8.2 is the contracting of a party, meeting the criteria of the bid documents, to implement the remediation works against agreed cost and time schedules.

Volume I

Step 8 Implementation of remediation

Task 8.3 Execution, supervision and verification of remediation works

Step 8: Implementation of remediation

Task 8.3: Execution, supervision and verification of remediation works

8.3.1 Introduction to and scope of Task 8.3

General description and connection to other Steps and Tasks
Task 8.3 concerns the execution of the remediation measures, as well as supervision and verification of the same.
The figure below shows how this Step is connected to preceding and following Steps and Tasks within the sequence of site assessment and remediation.

Activities
The following activities are performed in Task 8.3:
1) Prepare remediation measures;
2) Verify preparation of remediation measures;
3) Execute and manage remediation measures;
4) Verify remediation measures against contract and specifications;
5) Report verification results in a Remediation evaluation report.

Responsible parties
Activities 1 and 3 in this Task are typically carried out by technical specialists employed by a contractor. The team involved should demonstrate in-depth knowledge and experience of e.g. the remediation techniques and the characteristics of the contamination to be remediated.

Activities 2, 4 and 5 in this Task are typically carried out by technical specialists within a specialised consultant. It may be decided that these activities are assigned to SPCB, State and Central Government.

The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of remediation techniques and the physical, hydrological and social impact of techniques.

The verification and reporting (Activities 4 and 5) are performed on behalf of the client and should therefore be carried out by a person or a team independent from the contractor. This requires special attention in case the supervision is carried out by specialists employed by the contractor. This is likely to happen in case the contractor has entered into a Design, Construct and Management contract with the client.

In case the competent authority performs verification of the progress and results this is usually done in addition to the verification as described in Activity 4.

8.3.2 Guidance for performing the activities

This section presents concise guidance for the performance of the activities within Task 8.3. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document as well as in other sources.

Activity 1 – Prepare remediation measures

The responsible party for the execution of the remediation measures, typically a contractor, will commence by preparing a detailed plan for the execution of the measures according to the obtained permits (Task 8.1) and the contract (Task 8.1). Referring to the DPR, prepared in Step 6, may be in order, as that provides important background information on the remediation. Besides the technical aspects of the measures this plan should contain a health and safety plan, aimed at protection of both the onsite workers and inhabitants and other users of the site and its surrounding area. Elements a Health and Safety plan should include are listed in the *Checklist Health and Safety plan, Volume II-8.3-a*. The specific safety measures depend of course on the nature of contaminants, the local situation of the site and Health and Safety Regulations. Furthermore, the plan should provide for efficient organisation and logistics of the remediation measures. Examples of constraints the plan may need to deal with are presented in Box I-8.3.1 below.

Box I.8.3.1 Examples of constraints for execution of remediation measures

Example situation: remediation measures are to be executed in an area where other activities are ongoing, e.g. a production unit at an industrial site.

In this example situation, the following constraints to the intended remediation measures may apply:

- Limited workspace, e.g. for placement of remediation equipment, for temporary storage of waste or for an on-site treatment plant;
- Limited access to the site for vehicles and capacity;
- Limited or otherwise regulated time, e.g. when the remediation is part of broader rehabilitation activities;
- Buildings and their foundations. When excavation is intended these may need to be temporarily stabilised;
- Cables, wiring and pipes for transporting electricity and liquid raw materials or waste. These may need to be temporarily redirected.

Activity 2 – Verify preparation of remediation measures

Like the remediation measures themselves, their preparation is also verified. This verification typically includes checks on whether the required permits have been issued prior to the start of the work, on whether the health and safety plan is adequate (refer *Checklist Health and Safety plan, Volume II 8.3-a)*, on whether the authorities have been informed about the start of works, and on whether the stakeholder involvement has been adequately organised.

The verification of the preparations also includes a check on whether the data on the situation at the site are still in accordance with the actual situation. The basis for this check is the remediation plan (approved DPR), prepared in Step 6. Especially in case a long time has passed since the remediation plan was developed the situation may have altered. In such situations it may be necessary to have the Conceptual Site Model updated, so the intended remediation measures can be modified accordingly. In case of major changes in the situation it may even be necessary to modify the DPR (Step 6). Examples of such a situation are: mobile contaminants may have moved further through the soil with groundwater flow or some digging has taken place at the site causing a displacement of superficially present contaminated material.

Activity 3 – Execute and manage remediation measures

To determine whether the intended remediation measures can effectively meet the remediation objectives, pilot testing may be conducted. Depending on the situation this pilot testing can be carried out before detailed design of the remediation measures or before the start of execution of the remediation measures.

Execution
Execution of the remediation measures takes place according to the remediation plan. That plan should contain a clear outline of every measure, demonstrating how it is performed, its frequency (if periodic), parameters to be measured or sampled, target levels and what to do whenever either critical deviations or non critical deviations occur. For guidance on this last item refer to Volume I, Step 11, Activity 3. Including a description of the aim and background of measures can help to gain support from affected parties.

Management and reporting
The contractor periodically informs the client on the progress of the remediation measures. These reports should provide at least the following information:
- Progress of measures against the planning. Identification of delays or potential delays;
- Description and photographic records of the executed activities;
- Required modifications to the remediation measures;
- Necessity of activities not expected before and not agreed in the contract;
- Forecast of the activities and implications for the budget when extra activities are needed;

- If applicable, health and safety accidents or environmental incidents;
- Details of site visits made by regulators;
- Evidence (e.g. results of measurements) of conformance with permits, licenses and/or consents.

Relevant stakeholders on the site and in its surroundings should also be periodically informed on the progress. To them, the testing of nuisance caused by remediation activities may be of special interest.

Stakeholder	Interview objective	Level
Site owner	provide information, discuss progress	site
Site operator’s health facility director	provide information, discuss progress	site
Local businesses, residents and NGO’s	provide information, discuss progress	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	provide information, discuss progress	local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	provide information, discuss progress	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	provide information, discuss progress	national
Competent authority	provide information, discuss progress	level of competent authority

<u>Activity 4 – Verify remediation measures against contract and specifications</u>

During the execution of the remedial measures the supervisor periodically verifies the conditions at the site. The actions this entails will have been outlined in the verification plan, developed in Step 6. This plan would also provide the frequency of the actions by the supervisor, the samples to take, what needs to be reported and otherwise communicated etc. The intensity of the actions to be performed may in certain situations require permanent presence of the supervisor at the site.

The verification focuses on whether the contractor executes the measures in conformity with the outline in the remediation plan (DPR), developed in Step 6. In case of deviations from that plan the supervisor discusses the reasons for this deviation with the contractor. In case the deviation necessitates modifications to the remediation measures the supervisor may impose these on the contractor. In case a deviation leads to a critical situation the supervisor may recommend to modify the remediation plan (DPR) or even to inform the competent authority, who may decide to temporarily discontinue the execution of the remediation measures. Box I-8.3.2 provides practical information how to deal with deviations from the remediation plan.

Box I-8.3.2 Practical information on dealing with deviation of remediation plan by the supervisor

Although a contaminated site may have been investigated thoroughly, almost always the contamination in the soil and groundwater has a different appearance and magnitude compared to the description in the preremediation reports. Any soil investigation is dependent on a relatively small amount of sampling compared to the volume of soil and groundwater and as such will give a different picture than reality.

A remediation plan/DPR describes the activities necessary to approach the contaminated situation as assessed. If the actual contaminated situation varies from the assessed situation the remediation works should be adjusted. For instance if in a corner of a site contamination was expected but during excavation this contamination is not found, the excavated area can be reduced compared to the boundaries described in the DPR. This is a sensible strategy the supervisor has to approve. Normally the DPR describes how to deal with deviations of the actual situation.

Another example of such a situation that may call for modification of the remediation plan is where during excavation contamination turns out to be present in much deeper soil layers than previously expected while the ongoing remediation measures are not sufficient to reach that depth.

The supervisors' periodic verifications also serves to manage the environmental aspects of the remediation. An example of this is periodic sampling of excavated material to determine its potential for reuse. In case excavated material turns out to be contaminated the supervisor may direct that it should be transported to a treatment plant or to a TSDF. If not contaminated he may indicate appropriate reuse options.

The periodic verifications include the collection of data, in conformity with the verification plan. Usually this is achieved by taking soil samples at defined locations in the wall or floor of an excavation pit and sending them to an accredited laboratory for testing. The periodic verification can also involve measuring the water quality after treatment, measuring the thickness of a capping layer and monitoring the nuisance at site boundaries (noise, dust, odour, etc.). The time span of this periodic testing is in line with the time span of the remediation measures and can cover several years.

In case unforeseen events considerably change the situation at the site the supervisor may impose modification of the remediation measures. An example of such a situation is when, through demolishing a building and its foundations, contaminated material has accidentally ended up among clean soil material.

The supervisor should keep a log in which he records daily events at the site and results of any measurements. This log will later serve to prepare the Remediation evaluation report (Activity 5).

A checklist of elements of supervision and verification is presented in the *Checklist supervision and verification of remediation measures, Volume II-8.3-b*.

The supervisor can also have a role in the health and safety measures by signalling unsafe situations, upon which the contractor may need to take the appropriate actions.

One of the most vital tasks of the supervisor is to perform verifications at preset critical moments in the remediation process. Example of such moments is the moment when an excavation has reached its predefined boundaries: before supplementing the excavated pit with clean soil material, the supervisor should take samples from the pit wall and bottom to verify whether the remediation objectives have been met.

Activity 5 – Report verification results in a Remediation evaluation report

The collected information on the verification activities are reported by the environmental supervisor, refer *Checklist Remediation evaluation report, Volume II-8.3-c*. All data, including copies of analytical reports and testing results and a logbook of the remediation period, are added to the report. The results of the remediation are compared to the expectations described in the remediation plan/DPR, e.g. are the concentration levels of the soil samples below the target levels as described in the DPR?

In the Remediation evaluation report a.o. following questions should be answered:
- Was it possible to verify the remediation results?
- Is the remediation result acceptable compared to the expectations in the DPR?
- Has the remediation been carried out in the way it was planned and approved before?
- If not, were the measures adjusted accordingly?
- Is contamination not being removed which requires post remediation action?

This evaluation report is the basis for the client and for the competent authority to decide on approval of the environmental results of the remediation and to take a decision on the possibilities for future land use.

8.3.3 Task 8.3 output

The output of this Task 8.3 is a Remediation evaluation report, to be reviewed and approved by the competent authority during Step 9.

Volume I
Step 9 Approval of remediation completion

Step 9: Approval of remediation completion

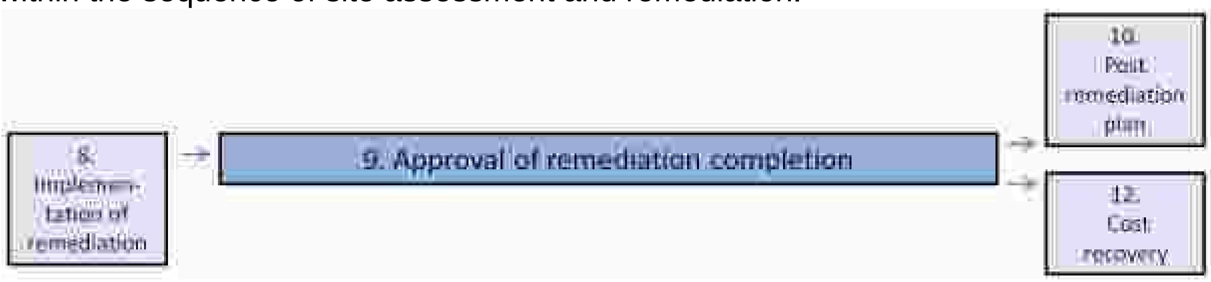
9.1 Introduction to and scope of Step 9

General description and connection to other Steps
Step 9 concerns the review and approval of the remediation activities by the competent authority.

After the remediation activities have been completed the activities and their results would have been presented in a remediation evaluation report (Step 8). These results need to be approved by the competent authority, based on a review of the same report, in this Step 9. In case the remediation has left no residual contamination on the site, the authority may unconditionally approve the remediation. In such a case steps 10 and 11 may be skipped altogether, so the next steps will be Step 12 Cost recovery, Step 13 Priority list deletion, and Step 14 Site reuse.

In case residual contamination has been left behind on the site after remediation, the competent authority may accompany the approval of the remediation with a decision that post remediation action needs to be carried out. In such a case, a post remediation plan will need to be developed in the subsequent Step 10.

Step 9 commences with a review of the remediation evaluation report plan developed in Task 8.3. It ends with the presentation of the decision.
The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.



Activities
The following activity is performed in Step 9:
1) Review the Remediation evaluation report and approval of the remediation completion.

Responsible parties
The activity in this Step is typically carried out by technical specialists within the competent authority for the remediation process.

The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of remediation techniques and the physical, hydrological and social impact of techniques, as well as awareness of social aspects and consequences for spatial planning.

9.2 Guidance for performing the activities of Step 9

This section presents concise guidance for the performance of the activity within Step 9. It is intended to enable the user to quickly gain an understanding of the necessary activity.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document.

Activity 1 – Review the Remediation evaluation report and approval of the remediation completion

Review of the remediation report
Step 9 primarily aims to review whether the results of the remediation, presented in the Remediation evaluation report, developed in Task 8.3, meet the expectations, raised by the agreed remediation design plan/DPR, developed in Step 6. A set of criteria for this review is presented in the *Checklist review and approval remediation completion, Volume II-9-a*.

Criteria for the success of the remediation can be very clear, e.g. reduction of the concentration of a certain parameter to below a certain level. In practice, it is not always easy to deal with such criteria. An example in Box I-9.1 below illustrates this.

Box I-9.1 Example of complication in dealing with remediation success criteria

Example situation: remediation was carried out by excavating contaminated soil material. During this excavation it turned out that the volume of contaminated soil material was considerably larger than expected based on the previous site investigation results. This because some soil material below a building foundation, where it could not be reached during the investigation, turned out to be contaminated. Upon encountering this material, the contractor has decided not to remove this contamination, due to disproportionate costs to reduce limited risks.

During review of the Remediation evaluation report, the competent authority may decide to accept the contractor's decision, under the condition that post remediation measures are implemented to control risks associated with the residual contaminated soil material.

Remediation projects may comprise several phases, e.g. when excavation of contaminated soil material was followed by the extraction and treatment of contaminated groundwater. Another example is an in-situ remediation where after an initial phase of installing the equipment a remediation period of several of years followed. In such situations the Remediation evaluation report should expressly discuss all phases of the remediation. A common situation is that the last phase of remediation covers a considerable time period. In such a situation a remediation evaluation report covering all phases but the last one can be considered. In practice, a period of one year is commonly used, after which reports on intermediate results of the last phase can be submitted for review and approval.

In cases where post remediation measures had been integrated in the remediation strategy upfront, it can be beneficial to simultaneously review the post remediation plan, developed in Step 10, if this is already available.

Approval of the remediation results and presentation of conclusions on next step
Based on the outcome of the review (Activity 1) the competent authority develops and presents a conclusion on approval of the remediation results. This conclusion should also contain an outline of the current situation at the site, as well as the possibilities for site use. Essentially three types of conclusion are possible:

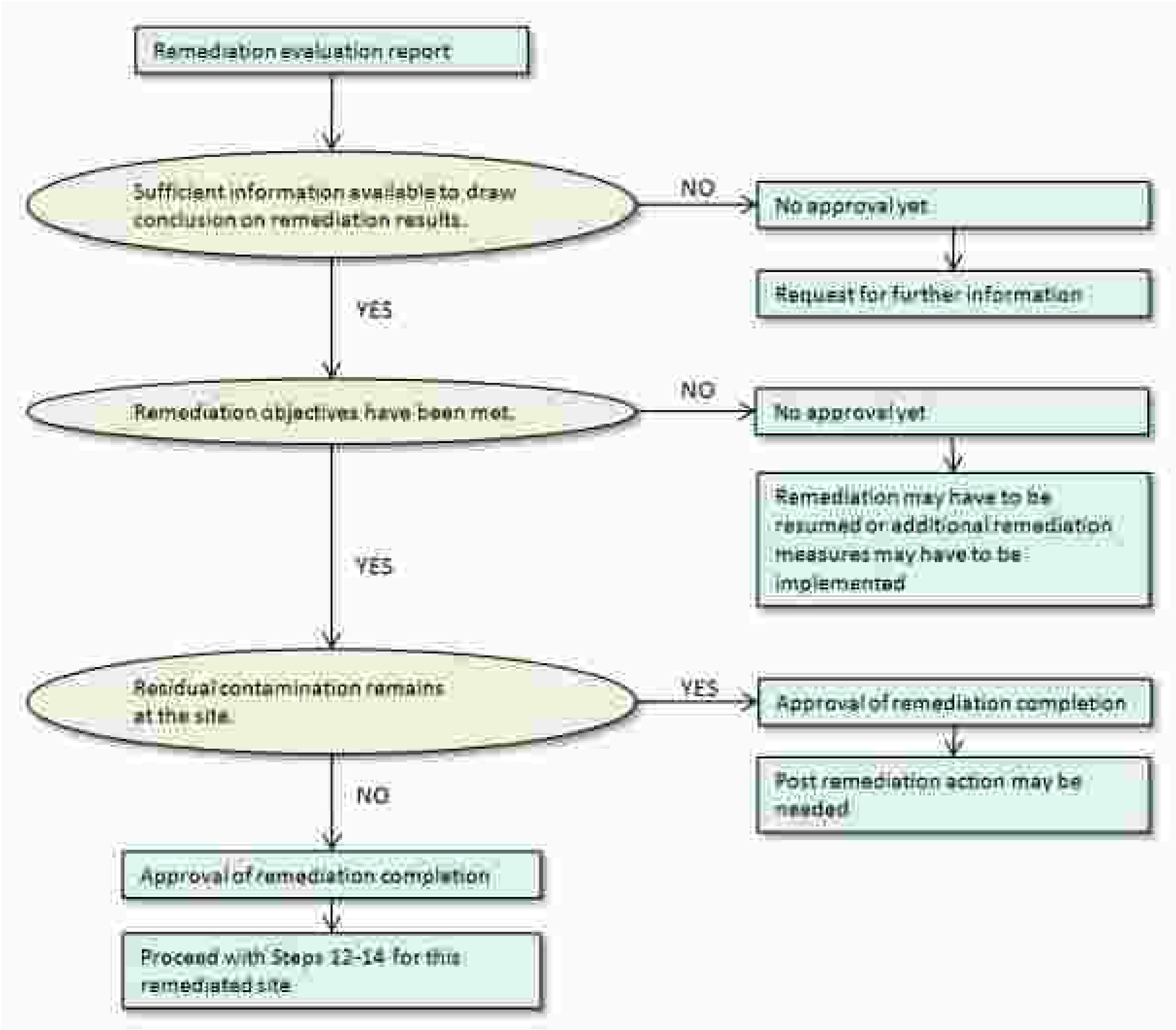
1. Gaps in the forwarded information bar a conclusion. In this case the competent authority may request completion of the remediation evaluation report, so as a conclusion can be prepared.

2. The remediation objectives have not been met. The competent authority may decide the remediation to be resumed or additional remediation measures should be implemented. In this case the competent authority may give appropriate instructions as to their implementation. In case this involves additional investigation the process is resumed at Task 5.1 Detailed site investigation. In case additional investigation is not needed the process is resumed at Step 6 Remediation design, DPR.

3. The remediation objectives have been met. The remediation phase may be formally terminated.
    a. residual contamination remains on the site. In this case post remediation measures may be needed. In case the Remediation evaluation report proposes such measures the competent authority may need to approve these measures (Step 10) and give instructions for implementation (Step 11). In case the Remediation evaluation report does not propose such measures, the competent authority may give instructions to develop such measures (Step 10) and for their implementation (Step 11);
    b. no residual contamination remains on site. In this case the competent authority may proceed with Step 12 Cost recovery, Step 13 Priority list deletion, and Step 14 Site reuse.

This review process is visualised in the flowchart below.

Figure I-9.1 Flowchart for review of remediation results and conclusion on next step.



9.3 Step 9 output

The output of Step 9 is a clear conclusion on approval of the remediation results. This conclusion should also contain an outline of the current situation at the site, as well as the possibilities for site use. Instructions for the next steps also form part of the output of Step 9.

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Step 10 Post remediation plan

Step 10 Post remediation plan

10.1 Introduction to and scope of Task 10

General description and connection to other Steps
Step 10 concerns design and approval of a Post remediation plan. Such a plan is required only when a remediation is completed while leaving residual contaminations at the site. In such cases site use restrictions are likely to be in force, and technical measures may be necessary to prevent future human and ecological risks and risks of spreading of the residual contaminations.

Step 10 commences with a review of the remediation evaluation report, developed in Task 8.3 and approved in Step 9, as that report establishes the need of post remediation measures. Step 10 ends with an approved post remediation plan, the basis for the implementation of the port remediation measures in Step 11.
The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.

Activities
The following activities are performed in Step 10:
1) Preparation of post remediation plan;
2) Review and approval of post remediation plan.

Responsible parties
The activities in this Step are typically carried out by technical specialists within the competent authority for the remediation process, or the appointed consultant. The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of post remediation techniques and the physical, hydrological and social impact of these techniques.

A review by the competent authority is required before moving to the next Step 11 Post remediation action.

10.2 Guidance for performing the activities of Step 10

This section presents concise guidance for the performance of the activity within Step 9. It is intended to enable the user to quickly gain an understanding of the necessary activity.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document.

Activity 1 Preparation of post remediation plan

The post remediation plan describes all the technical and supporting management activities such as monitoring, maintenance, repairs and corrective actions to keep a remediated site in such a state as to prevent future risks. The post remediation plan should provide for a long term guarantee to the competent authority for a long lasting and adequate risk control.

The nature of post remediation measures can be deceptively similar to certain types of remediation measures. Box I-10.1 below provides guidance in distinguishing the one from the other.

Box I-10.1 Post remediation measures versus remediation measures

Post remediation measures will start after the remediation works have been completed and the results have been approved by the competent authorities. Post remediation measures do not aim to remove the residual contaminants, but rather to control and fix the situation reached by the remediation measures and to prevent the residual contaminants to cause future human and ecological risks and risks of spreading. Post remediation measures typically are long term and can run up to several years or even decades.

By contrast, long term extensive remediation measures are performed during remediation. These measures resemble post remediation measures in that they are long term and can last up to several years. The difference with post remediation measures is that the long term extensive remediation measures are aimed to reach the remediation objectives by reducing the contaminant level. Such measures typically form part of in situ techniques, based on slow natural processes to degrade or precipitate contaminations.

The design of a post remediation plan should commence by a review of the remediation evaluation report, developed in Task 8.3 and approved in Step 9, as that report establishes the need of post remediation measures. In cases where residual contamination has remained at the site that report should also list the site use restrictions to prevent risks. Examples of these restrictions are presented in Box I-10.2 below.

Box I-10.2 Examples of site use restrictions

- no digging (either with or without human safety measures like gloves);
- no vegetable growing for human consumption;
- no use of groundwater for irrigation or human consumption;
- no cultivating of plants with roots growing to a depth > 0.5 m;
- no construction of residences (to prevent vapours from the soil to enter buildings);
- no site use change without prior consent by the competent authority.

Two different types of measures to prevent risks can be distinguished, examples of which are presented in Box I-10.3:

- *Management measures:* activities which are focused on compliance with the site use restrictions or the monitoring of a stable physical situation that can be disturbed by human impact or natural processes;
- *Technical measures:* activities which are focused on the maintenance and the continuity in operation of active measures.

Box. I. 10.3 Examples of post remediation measures

Management measures

- Registration of site use restrictions and administrative management of the land use;
- Monitoring compliance with site use restrictions;
- Raising of awareness;
- Monitoring of contaminant concentration levels in stable groundwater plume.

Technical measures

- Monitoring and maintenance of clean top layer covering contaminated material;
- Operation of geohydrological isolation of a groundwater plume, including operation of a pump and treat system;
- Maintenance of groundwater drainage system to prevent contaminated groundwater to enter residences;
- Monitoring of permeability of vertical barriers and maintenance of these barriers if necessary;
- Maintenance of the biological activity in the soil to be able to degrade remaining contamination;
- Maintenance of the monitoring system.

During the post remediation phase critical deviation points and non-critical deviation points may come up that might lead to future human and ecological risks and risks of spreading of the contaminations. These deviation points should be anticipated in the post remediation plan by outlining counter measures. Critical deviation points may result in additional site use restrictions. But if the risks due to the residual contaminations cannot be controlled by the post remediation measures, there may be a need to commence additional remediation measures. For the design and implementation of these measures a detailed project report (DPR), including an authorisation of the authorities is needed (Step 6). Examples of critical and non critical deviation points are presented in Box I-10.4 below.

Box I-10.4 Examples of critical and non-critical deviation points

An example of a non-critical deviation point is the following: the capping layer (covering a contaminated site) is slightly damaged. Due to the damage the thickness and/or the composition of the capping layer may not meet the original requirements anymore. By restoring the capping layer the situation at the site can be restored into the situation as it was directly after the implementation phase of the remediation.

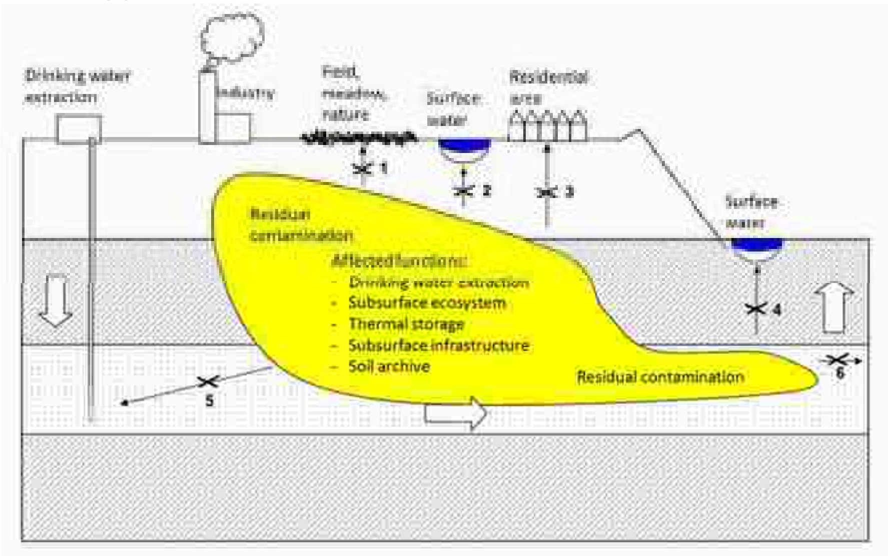
An example of a critical deviation point is the following: the concentration of contaminations in groundwater are unexpectedly rising to a non acceptable level. The reduction of the concentrations can only be realised by implementing additional removal of the contaminated source.

The post remediation plan should include a list of the potential critical and non critical deviation points, a list of action levels, how these levels can be detected in time, what kind of counter measures might be adequate, as well as the design of the decision process on counter measures. Monitoring is a useful tool to keep an eye on all deviation points.

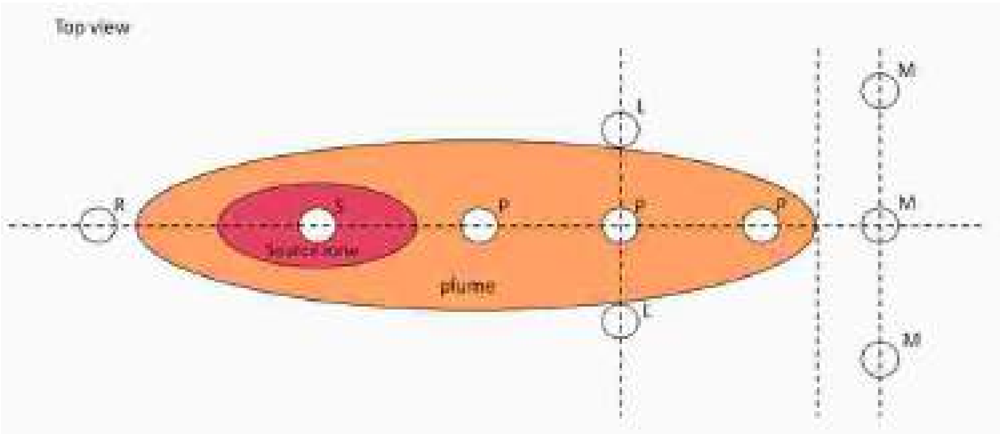
Strategy for monitoring groundwater
For monitoring of groundwater quality the following strategies may be applied (sometimes a combination of strategies is applied):

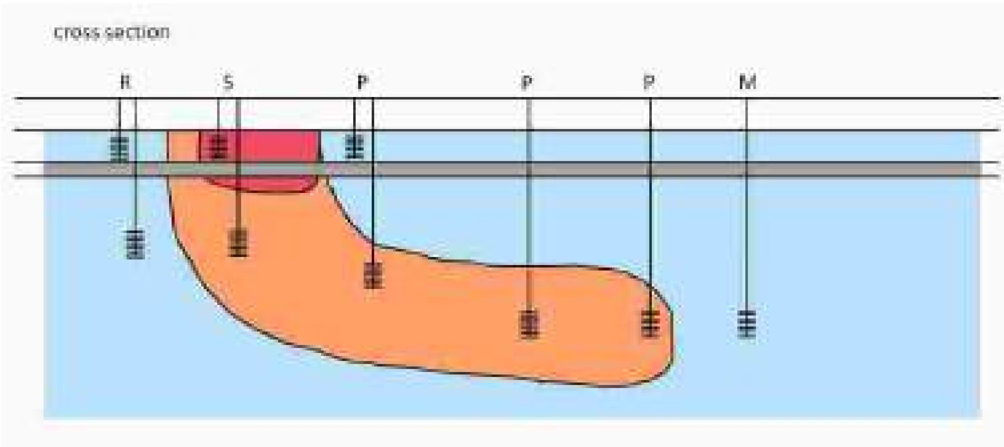
- Receptor based
- Plume based
- Flux based

1) Receptor based strategy
Monitoring should indicate whether the contamination in groundwater is threatening receptors. This strategy is often applied in case of short distance between contaminated plume and receptor. Between the end of the plume and the receptor at least one monitoring well must be placed. The figure shows an example of a plume of residual contamination, various receptors and routes (indicated by crossed out arrows 1 through 6) between contamination and receptors that need to be monitored.



2) Plume based strategy
Information about the fate and behaviour of the contaminated plume has to be collected in order to enable conclusions on future behaviour. Based on trend analysis over a couple of years of measuring it can be underpinned if a plume is still expected to be stable, to move, to grow or to decline.
Below two figures illustrate the basic idea for the pattern for monitoring wells. Explanation of the codes that show the purpose of each well: R (Reference for background level); S (Source); P (Plume); L (Lateral plume expansion); M (general Monitoring).





In the direction of the plume monitoring wells will be placed in following order: R-S-P-P-P-M. Transverse thereto following monitoring wells will be placed: L-P-L to detect deviations of expected transport direction and M-M-M to detect the front of the plume. Depth of the wells are depending on soil profile and plume dimensions. Often wells have to placed at multiple depths related to the permeability of the soil layers. Minimum number of monitoring wells is to have R-S-P-M in the direction of transport, one line of wells L-P-L across the plume perpendicular to the direction of transport and one line of wells M-M-M in front of the plume, also perpendicular to the direction of transport.

3) Flux based
Monitoring wells are positioned transverse to transport direction of the plume in order to measure the amount of contaminated material which passes through this plane. This strategy is often applied in case of multiple plumes which are spreading towards one receptor.

Other elements of a Post remediation plan
Practical aspects of the implementation of the post remediation activities should be part of the post remediation plan. Depending on the situation at hand those aspects typically include:
- Scheme of monitoring activities;
- Scheme of maintenance, repairs and replacement of parts of the post remediation system, e.g. groundwater pumping system, horizontal capping layer, monitoring wells;
- Log of all recordings, activities, contacts and results of the post remediation actions;
- Periodic reporting of the site status;
- Planning schedule for all activities described.

A management scheme is necessary to describe all tasks, responsibilities and persons or institutions to which these are addressed to. As management can only be effective if based on periodic status reporting, the post remediation plan should state the frequency of post remediation status reporting.

The *Checklist Post remediation plan, Volume II-10-a* provides a comprehensive overview of elements a full scale post remediation plan may contain. The post remediation plan is forwarded to the competent authority for approval.

Stakeholder consultation
A stakeholder consultation is needed, both to inform the stakeholders on the post remediation plan and to secure their support. The consultation may also yield information that can be useful in the final design of the post remediation plan. Whether or not to include interviews with stakeholders at district, state and national level may involve the weighing of economic aspects. As a result, this may for the state and national levels only be applicable to large scale sites.
The decision on land use post remediation needs to be taken at this stage. Therefore, the post remediation plan also needs to address this issue. This necessitates the involvement of a land use designation authority, which may take the shape of an interdepartmental committee with land use experts.

Stakeholder	Interview objective	Level
Site owner	exchange information, secure support	site
Site operator’s health facility director	exchange information, secure support	site
Local businesses, residents and NGO’s	exchange information, secure support	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	exchange information, secure support	local
Land Registration Office	discuss conclusion on land use post remediation	district / local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	exchange information, secure support	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	exchange information, secure support	national

Activity 2 Review and approval of post remediation plan

The competent authority reviews the post remediation plan. The *Checklist review and approval Post remediation plan, Volume II-10-b* provides guidance for this Activity. The competent authority may also find guidance in the text on Activity 1 above.

10.3 Step 10 output

The output of this Step 10 is a Post remediation plan, approved by the competent authority, describing all activities needed to prevent future human and ecological risks and risks of spreading of the residual contamination left on the site after the finalization of the remediation.

Based on this output the post remediation activities can be implemented in the subsequent Step 11.

Volume I
Step 11 Post remediation action

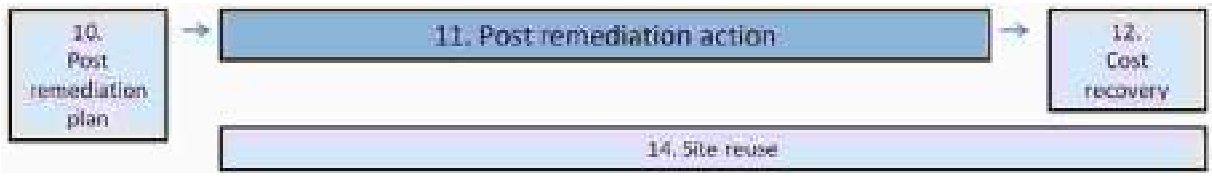
Step 11: Post remediation action

11.1 Introduction to and scope of Step 11

General description and connection to other Steps
Step 11 concerns the implementation of the post remedial action outlined in the Post remediation plan. This is required only when a remediation is completed while leaving residual contaminations at the site. In such cases site use restrictions are likely to be in force, and technical measures may be necessary to prevent future human and ecological risks and risks of spreading of the residual contaminations.

Step 11 commences with a review of the Post remediation plan developed and approved in Step 10. It ends if and when an approved Post remediation status report demonstrates that the residual contaminations do no longer require attention. In certain situations Step 11 may go on in perpetuity, which may or may not bar site reuse.

If the situation on the site allows it, Steps 11 and 14 (Site reuse) can be implemented simultaneously.
The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.



Activities
The following activities are performed in Step 11:
1) Prepare Post remediation implementation programme;
2) Outsource implementation of post remediation activities;
3) Implement post remediation activities;
4) Supervise and verify post remediation activities and prepare periodical Post remediation status report;
5) Periodically review and approve Post remediation status report.

Responsible parties
Activity 3 in this Task is typically carried out by technical specialists employed by a contractor. The team involved should demonstrate in-depth knowledge and experience of e.g. the post remediation techniques and the characteristics of the contamination involved.

Activities 1, 2 and 4 in this Task are typically carried out by technical specialists within a specialised consultant. The team involved should demonstrate in-depth knowledge and experience of e.g. the characteristics of contaminations (e.g. mobility, biodegradability), performance of post remediation techniques and the physical, hydrological and social impact of these techniques.

The supervision and verification are performed on behalf of the client and should therefore be carried out by a person or a team independent from the contractor. This requires special attention in case the supervision is carried out by specialists employed by the contractor.

Activity 5 has to be carried out by experts of the competent authority.

11.2 Guidance for performing the activities of Step 11

This section presents concise guidance for the performance of the activities within Step 11. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Wherever relevant, reference is made to more detailed information, both in Volume II and Volume III of the Guidance Document.

Activity 1 – Prepare Post remediation implementation programme

The approved Post remediation plan is the basis for the implementation of post remediation action. In this Activity this plan is translated into a Post remediation implementation programme, essentially a smart list of operational measures to be implemented, typically over a time frame of two to five years. Most operational measures during post remediation will be repeated periodically. The frequency of this will largely determine the time frame of the implementation programme: the higher the frequency the shorter the time frame of the implementation programme. The frequency of the operational measures typically is high whenever a site is situated in a dynamic area. This warrants revision of the implementation programme after a relatively short period of time, say two years. A high frequency of operational measures is also often seen during the initial phase of post remediation, after which it may gradually slow down. In that situation revisions of the implementation programme tend to last longer as the post remediation progresses. Aspects related to the contracting phase (see under Activity 2) can also influence the time frame of an implementation programme.

In case the post remediation measures are to be assigned to a third party (see under Activity 2 below) the Post remediation implementation programme can be a useful Annex to the Terms of Reference.

The nature of post remediation measures can be deceptively similar to certain types of remediation measures. Box I-10.1 (see Volume I, Step 10) provides guidance in distinguishing the one from the other.

Post remediation is a matter of measures periodically repeated over a relatively long period of time, from years to decades and even longer. This means two things: firstly, management is crucial and can only be effective if based on periodic status reporting (see under Activity 4). Therefore, the Post remediation implementation programme should state the frequency of Post remediation status reporting. Secondly, a Post remediation implementation programme should contain measures in all of the following categories: monitoring, inspection, maintenance, replacement, management.

Situations with layers capping a residual contamination in soil and with residual contamination in groundwater make for the majority of all post remediation situations. Box I-11.1 below presents examples of implementation measures in all five categories for situations with capping layers, while Box I-11.2 does the same for situations with residual contamination in groundwater.

Box I-11.1 Examples of post remediation implementation measures for situations with a layer capping contamination in soil

Situation: during remediation (Step 8) a clean layer has been installed isolating a volume of contaminated soil. The capping layer effectively prevents human contact with the contaminated soil. With that, the remediation objective of blocking the pathway between the contaminated soil (source) and humans (receptors) has been met. The remediation has been reported and the report has been approved by the competent authority, effectively concluding the remediation (Step 9). In order to ensure the remediation objective is maintained for as long as is deemed necessary, it has been decided that post remediation action is needed.
The Post remediation plan (Step 10) states that the post remediation measures should ensure the capping layer continues to prevent receptors to get in contact with the contaminated soil. Measures to that end have been described in a general sense. In this Step 11 these are translated into implementation measures, e.g. the following:

- *monitoring measures*: yearly inspection of the thickness of the capping layer. The thickness should be at least 90% of the thickness upon end of remediation. During the inspection the integrity of the capping layer should be guaranteed. Therefore non destructive inspections are preferred before destructive methods. Example non-destructive sample methods are GRP (ground penetrating radar), surface elevation levelling (settling of the contaminated layer below the capping layer will be a point of uncertainty), visual inspection (suitable for identifying unauthorised activities, but has its limitations as it is impossible to estimate the thickness of a layer. Visual inspections typically are only applicable to signal cracks, ruptures, settling, and slides or shearing along slopes). Typical destructive sample methods are digging (with possibility for lines repairs due to the digging) or drilling. Markers or signalling layers in the capping-contamination transition zone may help to improve the quality of radar or prevent damage by drilling.
- *inspection measures*: inspect the capping layer every 6 months and record visible signs of erosion, washing, settling, unauthorised digging and unauthorised reuse of contaminated material in the capping layer.
- *maintenance measures*: restore the capping layer whenever monitoring or inspection measures demonstrate this is needed.
- *replacement measures*: see maintenance measures.
- *management measures*: 1) instructions on site use, 2) awareness campaign to prevent damage to a capping layer, 3) official procedure for approval of specific types of site use, e.g. construction of drainage in a capping layer.

Box I-11.2 Examples of post remediation implementation measures for situations with a residual contamination in groundwater

Situation: during remediation (Step 8) contamination in groundwater has been removed to such a degree that risks have become acceptable. With this result the remediation objective of getting the source in an acceptable state has been met. The remediation has been reported and the report has been approved by the competent authority, effectively concluding the remediation completion (Step 9). In order to ensure the remediation objective is maintained for as long as is deemed necessary, it has been decided that post remediation is needed.
The Post remediation plan (Step 10) states that the post remediation measures should ensure the contaminant levels in the groundwater remain at such levels as to keep the risks acceptable. Measures to that end have been described in a general sense. In this Step 11 these are translated into implementation measures, e.g. the following.

- *monitoring measures*:
    - 1) measure groundwater flow and sample contamination levels, relevant for the given situation and according to the applicable standards, at the monitoring wells shown on a map in following sequence: month 1, 3, 6, 9, 12 and afterwards every 6 months (related to seasonal influences). Report results and advise corrective action whenever these show concentration levels become unacceptably high or whenever the contaminated groundwater spreads beyond the predefined border.
    - 2) measure groundwater discharge by the pumps installed for post remediation and sample contamination levels on day 1, 3, 7, 14 and afterwards on monthly basis. Report measurement results and advise maintenance or replacement measures whenever the discharge deviates unacceptably from the predefined intended volume or concentration levels become unacceptably high.
    - 3) measure the groundwater level on day 1, 7, 14 and afterwards on monthly basis, report results and advise corrective action whenever the groundwater level exceeds a predefined action level or whenever volatile contaminations threaten to enter building basements. Corrective action can be e.g. temporary intensified monitoring or a more comprehensive testing method.
- *inspection measures*: inspect the groundwater post remediation system every month, record visible signs of wear and advise maintenance or replacement measures whenever this is deemed necessary. Automated process logging and alarm system may be used.
- *maintenance measures*: take whatever measures are needed to maintain the groundwater pumps and the water purifying plant in good working order, e.g. to prevent the pipes from leaking.
- *replacement measures*: replace monitoring wells, active carbon in a water purifying plant or water pumps whenever this is needed to keep the system in good working order.
- *management measures*: instructions on site use.

As can be seen in the examples in the boxes above, the description of every measure should show how it is performed, its frequency (if periodic), parameters to be measured or sampled, target levels and what to do whenever either critical deviations or non critical deviations occur. For guidance on this last item see under Activity 3 below. Including a description of the aim and background of measures can help to gain support from affected parties.

Stakeholder involvement
Stakeholder involvement is crucial for most of the post remediation sites as the site use and post remediation system are closely interdependent. Therefore, prior to post remediation site users and the community should be involved. This can be done by the formation of a local committee, functioning as a part of panchayat in rural areas or as a ward committee in urban areas. Consultation of local political leaders can help in a balanced communication towards the community.

Owners, site users, inhabitants and others with primary dependence on the use of the site should be informed about the intended site use restrictions, as well as about the necessity and eventually the results of the post remediation measures. Authorities on spatial planning and land use should be informed as well (State Government, Urban and Rural Development Department, Revenue Department, Environment Department).

Activity 2 – Assign implementation of post remediation activities

Post remediation occurs in a variety of situations. The decision to assign/outsource the implementation of post remediation measures depends on the scope of the measures to be implemented and the position and involvement of the site owner to the site. Examples of situations where the site owner may take the post remediation or part thereof upon himself are presented in Box I-11.3 below.

Box I-11.3 Examples of situations where site owner may perform post remediation

- A TSDF owner who possesses the skills required to maintain a capping layer may decide to implement post remediation measures himself;
- An owner of an operational industrial site may decide to implement management measures (like supervision of compliance with site use restrictions) himself. In this situation, he may still outsource the remaining technical measures;
- An owner of an operational industrial site who possesses the skills required to perform groundwater sampling may decide to implement monitoring measures himself. In this situation, he may still outsource the remaining technical measures.

In case it is decided to assign/outsource the implementation of post remediation measures or part thereof the procedure commences by the preparation of bid documents. These should at least include Terms of Reference. These can then be used in the prequalification, which should result in the selection of able contractors. Guidance on the prequalification can be found in the *Checklist prequalification for remediation, Volume II.8.2-a*.

Post remediation action typically lasts a long time, which is often not even to be determined beforehand. Therefore the issue of the time frame merits special attention, in addition to the generic elements listed in the checklist mentioned above. Some of the options to be considered for this are:

- A predefined period, typically covering two or three years. This period should not be too short to optimise the costs and to minimise loss of information and hands on experience due to the handing over of the archive and change of project team;
- A period aligned with the time scope of the Post remediation implementation programme, developed in Activity 1 above;
- A period aligned with site redevelopment planning;
- A period aligned the planning of major maintenance and revisions of parts of the system. For example, if the life span of a water treatment plant is expected to be fifteen years, that may also serve as the contract time frame;
- A period aligned with intended site ownership transaction;
- An undefined period. This may imply the contract will only be terminated if and when the post remediation is terminated.

In a phase that may literally proceed in perpetuity, an exit strategy warrants special attention. Whenever residual contaminations turn out to have been removed, either by natural causes (e.g. by biodegradation) or by implemented measures, termination of the post remediation action may be considered. This action commences by evaluating the new situation in the Post remediation status report (see under Activity 4 below). In case it is expected the situation in the field will remain more or less stable forever it will be useful to formulate an exit strategy. This strategy should include criteria at which the post remediation measures may be terminated, and a method for termination.

Once the contractor has been selected, a contract will be formulated. The following issues merit special attention, largely with regard to the extensive time frame:

- Scope of the contract. While a contract including all risks and all replacement of expensive parts of the remediation system will be costly, it should be considered that the replacement itself can also be very dear. Examples are the complete restoration of a capping layer after it has been washed away by monsoons or the replacement of a bio-screen earlier than predicted;
- Continuity of data, information and experience with the site should be guaranteed during the entire contract period and beyond, e.g. by using a data management system (preferably online) and a provision that all data and experience shall be handed over to the client upon termination of the contract;
- Continuity of post remediation activities should be guaranteed. While a full guarantee cannot be given a good track record and a periodic payment schedule may offer some basic security.

<u>Activity 3 – Implement post remediation activities</u>

The party responsible for Activity 3 proceeds to implement the measures outlined in the Post remediation implementation programme, developed in Activity 1. During implementation any deviation from what is expected warrants adequate intervention. Whenever a deviation occurs, it should first be assessed whether corrective measures will enable restoration of the situation before the deviation occurred. If this is the case the deviation is regarded as non critical, otherwise it is a critical deviation.

Handling of a critical deviation
A critical deviation impacts the integrity of the post remediation system and therefore calls for immediate intervention to prevent damage and risks. Examples of critical deviations are presented in Box I-11.4 below.

Box I-11.4 Examples of critical deviation points

- Evaporation of volatile contamination into buildings is much higher than predicted in the Post remediation plan. All implemented measures fail to prevent human exposure to these contaminations. This means additional remediation measures like additional source removal (e.g. digging of contaminated soil), breaking of pathway (installation of additional ventilation or dam proof floors in the building) or relocating of receptors (evacuation of building residents) need to be implemented to terminate the exposure;
- Current or future site use differs from the use as described in the Post remediation plan or in the latest Post remediation status report and will result in future risks. Either enforcement on the unauthorised site use should be performed or additional remediation measures need to be implemented to accommodate this site use.

As a deviation of this magnitude cannot be corrected with limited effort the Post remediation plan may need to be revised, meaning going back to Step 10 (e.g. more stringent site use restrictions are imposed) and proceeding from there. It may even be necessary to implement additional site investigation and additional remediation measures. This means going back to Step 5 and proceeding from there. In such cases the following actions should be taken, in this order:
- Implement appropriate temporary safety measures to prevent damage and risks;
- In case of risks inform the competent authority about the situation;
- Register the event and inform relevant stakeholders;
- Design remediation objectives, based on the new situation (Step 5);
- Design corrective measures (DPR) to meet new remediation objectives, and acquire approval from competent authority (Steps 6 and 7);
- Implement the corrective measures, revise Remediation evaluation report (Step 8) and acquire approval from competent authority (Step 9);
- Revise Post remediation plan (Step 10) and Post remediation implementation programme (Step 11, Activity 1);
- Implement revised Post remediation implementation programme (Step 11, Activity 3).

Handling of a non critical deviation
A non critical deviation can be corrected with limited effort and impact on the post remediation system. The deviation may have no effect on the evaluation of data, the performance of the post remediation system or the use of the site. Corrective measures will enable restoration of the situation before the deviation occurred. Examples of non critical deviations are presented in Box I-11.5 below.

Box I-11.5 Examples of non critical deviation points

- Geohydrological isolation system does not lead to a predefined lowering of the groundwater level. As an additional post remediation measure the discharge of the groundwater pumps may be adjusted;
- Capping layer shows limited damage. As an additional post remediation measure this may be repaired;
- Monitoring well is jammed with mud, rendering groundwater sampling impossible. As an additional post remediation measure a new monitoring well can be installed.

A non critical deviation may be countered by implementing the following actions, in this order:

- Register the event;
- If necessary implement immediate actions to prevent further escalation into actual risks and damage;
- Inform the party responsible for the post remedial actions about the situation;
- Inform other stakeholders to prevent further escalation;
- Implement corrective measures to reset the situation to before the deviation occurred. These measures can be of very different nature, such as an increase of the monitoring intensity, additional communication on site use restriction, additional supervision on site use or minor changes in technical specifications to make the system more intrinsic reliable;
- Evaluate the Post remediation implementation programme and revise to prevent repetition of the event (Step 11, Activity 1).

Health and safety
During the implementation of the post remediation activities health and safety measures should be taken into account, refer *Checklist Health and Safety plan, Volume II-8.3-a*.

Stakeholder involvement
During implementation, the site users should be kept well informed on implementation of measures and progress of the post remediation. Signposting will clarify site use restrictions to the community.

Registration
All implemented post remediation measures should be well documented and archived in a post remediation archive. This archive should contain the following data: implemented measure, date or dates of implementation, person in charge, working method and documents and instruments used, sample identification and laboratory performing analysis (if applicable) and results. This archive will be the basis for reference in case of unexpected performance of the post remediation system and for the Post remediation status report, developed in Activity 4.

Activity 4 – Supervise and verify post remediation measures and prepare and verify periodical Post remediation status report

Supervision of implementation of measures
When post remediation involves a complex structure of measures it may be useful to have the implementation of the measures supervised.

Preparation of Post remediation status report
As stated before, post remediation typically lasts a long time, measured in years or in decades. Therefore, the management of post remediation merits special attention. For effective management of such long lasting action periodic status reporting is needed. The frequency of these reports should be stated in the Post remediation plan (Step 10) as well as in the Post remediation implementation programme (see under Activity 1 above).

The periodic Post remediation status report should present a solid insight in the status of the site at the moments predefined in the Post remediation plan and in the Post remediation implementation programme. Based on this report the competent authority should be able to review the implementation of the post remediation measures and to draw conclusions on whether the risks are actually addressed in correspondence with the description in the Post remediation plan.

The preparation of a periodic Post remediation status report commences by analysing the results of the implementation of the measures (see Activity 3), to be found in the post remediation archive. These results should be especially screened on inconsistencies and deviations from the objectives preset in the Post remediation plan. The results are then summarised in the Post remediation status report, followed by an evaluation of the present status of the site. The report should also include conclusions on the functioning of the post remediation system, and, if applicable, suggestions for modifications thereof. In case this kind of suggestions are made, the Post remediation implementation programme should be revised accordingly (see Box I-11.6 below) and the suggested measures implemented.

The *Checklist Post remediation status report, Volume II-11-a* presents an overview of elements to include in the Post remediation status report.

Verification of Post remediation status report
The Post remediation status report is typically prepared by the party responsible for the implementation of the post remediation measures. In case of potential conflict of interest the Post remediation status report should be verified by an independent third party. In such a situation, this third party should be authorized to perform his own measurements and samplings for verification of the reported results.

Review of Post remediation status report
The Post remediation status report should be forwarded to the competent authority for review and approval (see under Activity 5 below).

Box I-11.6 Optimisation of the Post remediation implementation programme

The Post remediation plan describes the technical and management measurements needed to prevent future human and ecological risks and risks of spreading of the contaminations due to residual contaminations. During the execution of the post-remediation activities it may be concluded that the intensity of the post-remediation activities can be lowered without risks. For example when the results of monitoring indicate that concentration levels are continuously dropping. Using the CSM tool this process can be understood and it is predicted that concentrations will not increase in the future. Using this knowledge the monitoring frequency can be lowered accordingly.

Using this approach, theoretically all technical activities can be reduced to zero. Management activities can also be reduced but a minimum level of management will be needed as long a contaminations are present. It is very well conceivable that the communication on site use restrictions at the starting point of a redevelopment plan is a good example of the minimal level of management activity.

Activity 5 – Review and approval of Post remediation status report

The competent authority reviews the Post remediation status report. The *Checklist review and approval Post remediation status report, Volume II-11-b* provides guidance for the performance of this Activity.

In case the Post remediation status report proposes modifications to the post remediation system the competent authority may need to authorise these modifications.

In case the Post remediation status report proposes termination of the post remediation measures the competent authority will need to authorise this termination. In such cases a previously developed exit strategy should be present and should be used as a basis for this important decision.

11.3 Step 11 output

The output of this Step 11 is a Post remediation status report, approved by the competent authority, describing the current status of the site with ongoing post remediation measures.

Based on this output the post remediation measures can be continued according to the guidance in this Step 11, or, in some cases, terminated.

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Step 12 Cost recovery

Step 12: Cost recovery

12.1 Introduction to and scope of Step 12

General description and connection to other Steps
Step 12 concerns the activities required to recover the costs for the previously undertaken assessment, remediation and post remediation measures in case the costs have been funded by the government. This step is mostly concerned with organisational, legal and financial aspects. From a technical point of view it is important to present a clear overview of the costs which have been involved in the assessment and (post) remediation activities.

The figure below shows how this Step is connected to the preceding and subsequent steps within the sequence of site assessment and remediation. After each Step with large financial consequences action may be undertaken to recover costs. This regards not only the remediation works (Step 8) and the post remediation action (Step 11) but costs involved for preliminary investigation (Step 2) remediation investigation (Step 5) and development of DPR (Step 6) may be significant as well.

Activities
Within this step a number of activities are to be performed. Most of these activities are on institutional, legal and financial aspects. For guidance on those activities we refer to the National Program for Remediation of Polluted Sites (Task 4 report, PWC Dec. 2015). Here, the guidance focuses on the one activity with technical/financial aspects:

1) Prepare cost overview of executed assessment and (post) remediation works

Responsible Parties
The activity listed above will typically be performed by technical, legal and financial specialists of the competent authority may be supported by the specialized agency or consultant which have been involved in the DPR phase or the remediation phase of the project. For various elements of the cost estimation information from different authorities may be required.
The team involved should be able to assess the costs and to link the costs presented to the information in the technical reports. Review is typically performed by senior staff members.

12.2 Guidance for performing the activity of Step 12

This section presents concise guidance for the performance of the activities within Step 12. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Activity 1 – Prepare cost overview of executed assessment and (post) remediation works

Where sites have been remediated using dedicated government funds, fully or partially, an attempt may be made to recover costs from the liable party.

In order to prepare an adequate cost overview it is required to identify which measures had to be taken for assessment, remediation and possible post remediation measures of the contaminated site. The following information should be collected:

- Evaluation reports of the remediation and post remediation works;
- The cost overviews of involved contractors, consultants, site investigators, laboratories, research institutes, other third parties and of involved governmental organisations;
- The DPR and the estimated remediation costs before start of the remediation. During Step 6 the cost estimation has been developed aimed to allocate/raise funds. This cost estimate, which should consist of a detailed listing of cost elements, should be used to compare to the actual involved costs, refer *Example format cost estimation remediation, Volume II-6-b*.

The costs involved may not only include the technical measures of the remediation. The preparation of the work, including costs for demolishing building or replacement of inhabitants may be included as well. The costs for management, supervision and verification of the remediation and post remediation works should be included too. The previous costs of investigation of the site and preparation of the remediation design may be summarized to the total of relevant costs.

The remediation may have been combined with redevelopment of the site. It is important to distinguish costs for remediation and costs for redevelopment (e.g. a situation where an existing building has been demolished before remediation and reconstruction could take place. The demolition costs may be designated to the remediation as well as to the reconstruction. If there haven't been made appointments on these issues this may be an important point for discussion when trying to recover costs.

12.3 Step 12 output

The output of this Step 12 is the overview of costs related to the executed assessment of the site, the preparation and execution, supervision of the remediation and post remediation works.
With this cost overview the necessary activities to recover the costs can proceed.

Volume I

Step 13 Priority list deletion

Step 13 Priority list deletion

13.1 Introduction to and scope of Step 13

General description and connection to other Steps

Step 13 concerns the deletion from the Priority list of a site where previous contamination has been remediated to such a degree that risks no longer exist or are deemed acceptable.

In case the remediation has left no residual contamination the competent authority would have declared the remediation to be completed and cleared the site for reuse. Where such a site was listed on the Priority list the competent authority for that list would in this Step 13 only need to mark the site as remediated and delete the site from the Priority list. In that situation there are no technical aspects to be discussed in this Step.

In case the remediation has left residual contamination the competent authority would have declared the remediation to be completed (Step 9). After that a post remediation plan would have been prepared and subsequently approved (Step 10), after which the post remediation action (Step 11) can commence to prevent future human and ecological risks and risks of spreading of the contaminations. In such a case site use restrictions are likely to apply. Step 13 commences with the assessment of applicable site use restrictions and ends with the marking of the conclusions on this in the database.

The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.

Activities
A number of activities are performed in Step 13. In this document only the technical aspects to these are discussed:

1) Assess and record site use restrictions.

Responsible parties
The activities in this step are typically carried out by the competent authority for the assessment and remediation process. The team involved should demonstrate ability to interpret the information and recommendations of site remediation works and post remediation status reports. This requires in-depth knowledge of and experience with the characteristics of contaminations (e.g. mobility, biodegradability) and its potential effects on humans and the environment.

13.2 Guidance for performing the activity of Step 13

This section presents concise guidance for the performance of the activities within Step 13. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Activity 1 – Assess and record site use restrictions

The situation discussed here is that of a remediated site with residual contaminants present at the time of commencement of this Step 13.

The presence of the residual contaminants is likely to have resulted in site use restrictions. These would be outlined in the post remediation plan (Step 10). In case the post remediation action is ongoing, the site use restrictions could also be outlined in the latest post remediation status report (Step 11). The party responsible for this Step 13 needs to assess these site use restrictions and have them recorded in the computerized database of contaminated sites maintained and updated by the competent authority.

Stakeholders need to be informed on the deletion of a site from the priority list. In case site use restrictions are imposed, these need to communicated to the stakeholders, as do any changes in the site use restrictions.

Stakeholder	**Interview objective**	**Level**
Site owner	provide information	site
Site operator’s health facility director	provide information	site
Local businesses, residents and NGO’s	provide information	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	provide information	local
In case site use restrictions need to be formally recorded: Land Registration Office	provide information	district / local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	provide information	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	provide information	national
Competent authority on land matters	discuss conclusion	district / local

13.3 Step 13 output

The output of this Step 13 is the deletion of the site from the Priority list and the registration of the restrictions that apply to the use of the site that needs to be recorded in the database of contaminated sites.

Volume I

Step 14 Site reuse

Step 14: Site Reuse

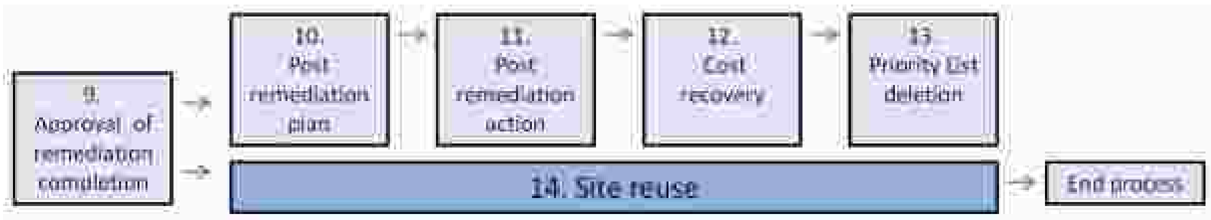
14.1 Introduction to and scope of Step 14

General description and connection to other Steps
Step 14 concerns the reuse of the remediated site. Step 14 commences with the handover of control of the site to the appropriate party, i.e. the former or the new site owner.

In case the remediation has left no residual contamination the competent authority would have declared the remediation to be completed and cleared the site for reuse (Step 9). Where such a site was listed on the Priority list the competent authority for that list would have marked the site as remediated (Step 13). In that situation there are no technical aspects to be discussed in this Step 14.

In case the remediation has left residual contamination the competent authority would have declared the remediation to be completed (Step 9). After that a post remediation plan would have been prepared and subsequently approved (Step 10), after which the post remediation action (Step 11) can commence to prevent future human and ecological risks and risks of spreading of the contaminations. If the situation on the site allows it, Steps 11 (post remediation activities) and 14 (site reuse) can be implemented simultaneously. This Step 14 presents guidance to the technical aspects of site reuse in such a situation.

The figure below shows how this Step is connected to preceding and following Steps within the sequence of site assessment and remediation.



Activities
The following activities are performed in Step 14:
1) Anticipate to site use restrictions;
2) Arrangements to enable post remediation action.

Responsible parties
The activities in this Step are typically carried out by the competent authority and the future site owner.

14.2 Guidance for performing the activities of Step 14

This section presents concise guidance for the performance of the activities within Step 14. It is intended to enable the user to quickly gain an understanding of the necessary activities while at the same time keeping an overview of the sequence of activities.

Activity 1 Anticipate to site use restrictions

The situation discussed here is that of a site at which remediation activities have been carried out but residual contaminants are still present at the time of handover of control to the new site owner.

The presence of the residual contaminants may have resulted in site use restrictions. These would be outlined in the post remediation plan (Step 10). In case the post remediation action is ongoing, the site use restrictions could also be outlined in the latest post remediation status report (Step 11). Violation of these site use restrictions may result in risks to human health or to the environment or in risks of spreading of the residual contaminants. Apart from the damage this may inflict, it is important to note that, depending on the legal situation, the site owner or the site user may be held responsible for this damage.

Change of site use not authorised by the post remediation plan or the latest post remediation status report will result in a critical deviation. This could imply that the site use should be reconsidered or that additional remediation measures need to be implemented to accommodate this site use. Where this occurs refer to Step 11 Post remediation action for guidance.

In case site use restrictions are imposed, these need to communicated to the stake-holders, as do any changes in the site use restrictions.

Stakeholder	**Interview objective**	**Level**
Site owner	provide information	site
Site operator's health facility director	provide information	site
Local businesses, residents and NGO's	provide information	site and direct vicinity
Municipal authorities. In case the potential contamination may include groundwater or surface water, including Water Supply and Sanitation	provide information	local
Land Registration Office	provide information on the change in land value for the revenue records	district / local
State authorities, including SPCB and, in case the potential contamination may include groundwater, Groundwater Authority	provide information	state
For large scale site: national authorities, including CPCB, Surveyor of India and Central Ground Water Board	provide information	national
Competent authority on land matters	discuss conclusion	district / local

Activity 2 Arrangements to enable post remediation action

The organization responsible for the post remediation action should have access to the site to implement the actions as outlined in the post remediation implementation programme or in the latest post remediation status report (Step 11). It is important to note that these actions may take place over an extensive time frame, expressed in years or even in decades or in perpetuity, and may in cases considerably affect site use. Where this occurs the competent authority may consider a temporary land use claim.

In case it is decided, by the competent authority or by the site owner, that the site owner will perform some or all post remediation action, the site owner can refer to Step 11 for guidance. He should note that all results may be subject to verification by an independent third party and will be subject to approval by the competent authority.

14.3 Step 14 output

The output of this Step 14 is, if necessary, a series of arrangements to enable implementation of post remediation actions as well as proper and effective site reuse simultaneously.

Volume I
Glossary

Volume I
Glossary of terms and topics

A

term / topic	definition
accreditation criteria	Criteria to be met for certification of a specific task or technical operation.
anthropogenic	Related to human activities.
aquifer	An underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

B

term / topic	definition
background concentration	The concentration of a substance in ground water, surface water, air, sediment, or soil at a source(s) or nearby reference location, and not attributable to the source(s) under consideration. Background samples may be contaminated, either by naturally occurring or manmade sources, but not by the source(s) under consideration.
biodegradability	Capability of being decomposed by bacteria or other living organisms in either one or more steps of decomposition and thereby lowering the concentration levels. Often associated with degradability of contaminants. Intermediate products may result in temporary rise in toxicity (e.g. vinyl chloride).
bioremediation	The use of either naturally occurring or deliberately introduced microorganisms to consume and break down environmental contaminations, in order to clean a polluted site
boring / borehole	Penetration into the subsurface with removal of soil/rock material by using, e.g., a hollow tubeshaped tool.

C

term / topic	definition
calibration	Mark (a gauge or a reading of an instrument) with a standard scale of readings.
competent authority	The public organisation bearing primary responsibility for the legal decisions, except those taken by a court of law, related to the assessment and remediation of a particular contaminated site or probably contaminated site.
Conceptual Site Model	A written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system.
constraints	Issues that do not have an impact on the remediation objectives or requirements, but that may affect how these objectives can be achieved.
complete removal	Removal of al contaminants from the soil or groundwater to a natural background level by the implementation of a remediation option
composition of the soil	The different parts (minerals, organic material, etc.) of which the soil is made of; the way in which the different parts are organized giving it a specific structure (e.g. geohydrological anisotropy)
containment	Control of migration of gaseous, liquid or solid contaminated media from a site by use of measures, such as covering systems, vertical in-ground barriers and in-ground horizontal barriers; depending on sitespecific factors, these measures may be used alone or in combination.

contaminant	Any substance, that is potentially hazardous to human health or the environment and is present in the environment at concentrations above its natural or background concentration.
contaminated site	A contaminated site is a delineated area consisting of aggregation of contamination sources, the areas between contamination sources, and areas that may contain contaminants due to migration from contamination sources. If on the basis of preliminary site assessment or preliminary site investigation or detailed site investigation, the constituents and characteristics of contaminants discharged or otherwise come to be located at the site, exist at or above Response levels and in conditions including possible combination of contaminants and interaction between contaminants and/or environmental constituents which pose existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity, in such case the site may be determined as contaminated site.
contamination	Discharge of contaminant at a site or migration of contaminant to a site.
contour maps	A map marked with contour lines connecting points of equal values (e.g. concentration level, hydraulic head).
cost benefit analysis	A systematic process for calculating and comparing costs and benefits of a remediation. The purpose is either to determine if it is a sound investment and decision or to provide a basis for comparing two or more remediation options.
cost effective	A form of economic analysis that compares the relative costs and outcomes of two or more remediation options. The analysis is often used where it may be inappropriate to monetize health effect.
cost recovery	Where sites have been rehabilitated using government funds, fully or partially, an attempt has to be made to recover the costs from the liable party. This may also be possible for orphan sites also.
critical deviations	Observed deviations of the CSM or the (post) remediation that will result in e.g. a de-functioning of the remediation technique, affect on the functional use of the site, the quality of the monitoring.

D

term / topic	**definition**
delineation	Process of finding boundaries of contamination at a contaminated site.
desk study	The gathering of information (geohydrology, history, etc.).
detailed site investigation	Main stage of intrusive site investigation, which involves the collection and analysis of soil and other media as a means of further informing the conceptual model and the risk assessment. This investigation may be undertaken in a single or a number of successive stages.
deviation point, critical	Event or development, occurring during post remediation, that is of such a kind that counter measures to restore the situation as reached by the remediation cannot be effective within the scope of the original post remediation plan.
deviation point, non critical	Event or development, occurring during post remediation, that is of such a kind that counter measures to restore the situation as reached by the remediation can be effective within the scope of the original post remediation plan.
discharge	Any act of spilling, releasing, leaking, dumping, pouring, pumping, emitting, emptying, injecting, escaping, leaching or disposing contaminants into the environment including drums, barrels, containers containing such contaminants.
Dispersion	*see migration*

DPR; Detailed Project Report	Report which provides details of the technical remediation activity to be conducted, cost and time of rehabilitation, stakeholder engagement, and post remediation monitoring.
drilling	Usually a vertical penetration into the subsurface with removal of soil/rock material by using motor-driven drilling equipment

E

term / topic	definition
ecological risk	Risks for ecology are formed when the biodiversity is affected (the contamination could cause a decline in species), when the recycling functions are affected and when bio-accumulation and poisoning can take place.
ecosystem	An ecosystem is a community of living organisms (plants, animals and microbes) in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system.
environment	Environment includes water, air and land and the inter- relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organism and property.
environmental and social impact assessment	the analyses and evaluation of the impact of soil remediation on the environment and/or society.
environmental transport	Movement of a chemical or physical agent in the environment after it has been released from a source to an environmental medium, for example, movement through the air, surface water, groundwater, soil, sediment, or food chain.
evaluation report	Report describing the execution and verification results of remedial actions.
evaporation	phase change from liquid into vapour
excavation	Removal of soil, fill, sediment, etc., from the ground for treatment or disposal.
exploratory holes	Drillings through which observations, samplings en measurements can be executed in order to get a better understanding of the Conceptual Site Model enabling site investigation and remediation.
exposure route	The process by which a contaminant or physical agent in the environment comes into direct contact with the body, tissues, or exchange boundaries of an environmental receptor organism, for example, ingestion, inhalation, dermal absorption, root uptake, and gill uptake.
ex-situ	Where contaminated material is removed from the ground prior to above-ground treatment or encapsulation and/or disposal on or off site.

F

term / topic	definition
fieldwork	Practical work (sampling, testing, measurements, observations) conducted by a researcher in the natural environment, rather than in a laboratory or office.
fitness for use	A remediation goal that meets a predefined site use, under anticipated (generic fitness for use) or specified user conditions (site specific fitness for use).
flux	The action or process of flowing or flowing out expressed as the amount of a substance passing a boundary within a specific time lapse.

G

term / topic	definition
generic remediation target levels	A preset level of concentration of a specific contaminant to be achieved without taking into account any site, area or site specific requirements are to be assessed.
groundwater	Water which is being held in, and can be recovered from, an underground formation.
groundwater level	Underground surface below which the ground is wholly saturated with water.
groundwater quality	The physical, chemical, and biological qualities of groundwater.

H

term / topic	definition
habitats	The natural home or environment of an animal, plant, or other organism.
human health	The health of human beings possibly affected by a contaminated site. (related to the NPRPS).
toxic substances	Any substance or preparation which, by reason of its chemical or physico-chemical properties or handling, is liable to cause harm to human beings, other living creatures, plant, micro-organism, property or the environment.
hazardous waste	Any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances as defined in "Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008".

I

term / topic	definition
identification	Identification of probably contaminated sites is a legally mandated, structured procedure for identifying polluted sites and submitting their details for further investigation to authorities.
impermeable	Not allowing fluid to pass through.
Independent third party	A party not related to the case in any way. Commentary: in certain cases it is imaginable that the independent party is the competent authority. Examples of parties who cannot be regarded as independent party are site owner, any site occupier and any party involved in the site’s development.
industrial processes	Processes in accordance with ‘Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008’.
in-situ	Where contaminated material is treated without prior excavation (of solids) or abstraction (of liquids) from the ground.
investigated site	If on the basis of such assessment or investigation, the contaminants exist at or below screening levels and there is no existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity, in such case the site may be determined as investigated site.
investigation strategy	Plan of action designed to achieve of the CSM necessary for a specific step in the remediation process.
isolation	*see containment*

L

term / topic	definition
land use and site activity	Generic land use including residential, agricultural, industrial, commercial or public use and any site specific activity, whether designate in a plan in force by law or the actual use of such land or site, that may expose a receptor to a contaminant including but not limited to use of or contact with soil, use of or contact with surface water or municipal water supply and abstraction and use of or contact with groundwater and related activities including construction, excavation, drilling, demolition, industry, operation, process, residence, commerce, trade, entertainment, recreation, education, cultivation and movement of vehicles and people. Categories of land use applied in this report: Agriculture land, Waste land, Water bodies, Forests, Habitation settlement; Commercial, Industrial, Mixed, Other.
logbook	Systematic daily or hourly record of activities, readings, measurements, events, and/or occurrences.
long term extensive remediation measures	measures performed during remediation which may run for long periods of time (up to several years) to reach the remediation objectives.

M

term / topic	definition
maintenance	Activities carried out to ensure that remediation performs as required over a specified design life.
management of polluted / contaminated sites	Activities to respond to the (probable) threats to human health and/or the environment caused by contaminated sites. These activities can contain technical, legal, institutional and financial elements.
menu of options	Overview giving insight in the most likely ('prioritized') remediation objectives, most likely (non)technical choices for remediation measures and specific conditions or alternative approaches in a variety of settings for different types of contaminated sites.
migration	Transport of contaminants / constituents through soil and/or surface water.
migration pathway	The course through which contaminants in the environment may move away from the source(s) to potential receptors.
mobile substances / mobility	Matter possibly consisting of or containing contaminants that has the property of displacement in soil, groundwater or surface water due to different natural or chemical processes like e.g. mass flow, gravity flow, osmosis, mass transport, leaching
monitoring	Process of repetitive observation, for defined purposes of one or more elements of the environment according to pre-arranged schedules in space and time, using comparable methods for environmental sensing and data collection.
monitoring wells	Groundwater sampling point from which the quality (amount of contaminants, pH, minerals, etc.) of the groundwater can be determined.
multifunctional	The property of a site that it can be used for any kind of use without any restrictions due to the presence of contaminants.

N

term / topic	definition
Priority list	A list of confirmed contaminated sites ranked according to prioritization criteria to determine the order in which sites are to be remediated.
natural background concentration	Concentration of a substance that is derived solely from natural sources (i.e. of geonic origin), commonly expressed in terms of average, a range of values or a natural background value.
natural contaminants	Substances present in a relative high concentration level without antropogenic cause.

natural soil processes	Chemical, biological or physical soil characteristics that determine accommodation or buffering of changes in soil quality.

O

term / topic	definition
observation wells	*see monitoring wells*

P

term / topic	definition
pathway	Path a chemical takes from a source to a receptor. Each exposure pathway links a source to a receptor.
performance criteria	Criterion under which the remediation options can be implemented.
permits	An official document giving a party authorization to implement a certain activity.
plume	Contaminated groundwater containing constituents derived from the source of the contamination.
point source contamination	Distinct and delimited contamination emitting contaminated material to its surrounding (i.c. groundwater, vadose zone, free air, surface water) or plants, animals and microbes.
pollutant linkage	The combination of a contaminant, a receptor and a pathway can create a risk when they are linked together.
polluted site	Areas where hazardous substances exist at levels and in conditions which may pose existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living creatures, plants, micro-organisms, property, water quality or the environment in general, determined in the manner prescribed.
post remediation activities / measures	Activities necessary after the physical clean-up activities have been completed, in order to manage the situation regarding possible negative effects of remaining contamination. These activities can have technical, legal, institutional or financial aspects.
post remediation implementation programme	Programme for planning of operational activities in the post remediation phase. Such programmes may be aimed at the planning of monitoring, inspection, maintenance, replacement and management activities.
post remediation monitoring	Monitoring of the activities necessary after the physical clean-up activities, in order to manage the situation regarding possible negative effects of remaining pollution. These activities can have technical, legal, institutional or financial aspects.
post remediation plan	Plan describing all technical and supporting management activities needed to keep a remediated site where residual contamination remained in such a state as to prevent the residual contamination to pose risks to human health, the environment or spreading.
precipitate	Formation of a solid in a solution or inside another solid during a chemical reaction or by diffusion in a solid
preliminary investigation	A preliminary investigation of the site shall be conducted to understand if the site poses no/some threat to human health and environment and site inspection is then carried out for sites that have some threats by taking samples of air, water and soil at the site.
preliminary site assessment	Investigation if activities at a site might have caused contamination (reconnaissance) and confirmation of the presence or absence of contamination by limited sampling.
primary source	Contaminations found in the soil on a place where they initially entered the soil. E.g. the area immediately around a leaking oil drum
prioritization criteria	Criteria used to make a priority for assessment and rehabilitation of contaminated sites under NPRPS.

probably contaminated site	A probably contaminated site is an area (whether or not delineated) where the presence of contaminants is suspected but not conclusively determined or where contaminants exceed specified standards but the threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property with regard to present or future land use and site activity is not conclusively established. A probably contaminated site may require further investigation to establish whether it is a contaminated site that requires remediation. The area may consist of aggregation of contamination sources, the areas between contamination sources, and areas that may contain contaminants due to migration from contamination sources.
pump and treat	Extraction and subsequent treatment (purifying plant) of contaminated groundwater. Effluent is either injected into the soil again or disposed onto an open water system.

Q

term / topic	**definition**
QA/QC for site assessment	The combination of quality assurance, the process or set of processes used to measure and assure the quality of a site assessment, and quality control, the process of meeting the results of a site assessment to standards.
quality	Description of the chemical quality of the soil, groundwater, sediment or surface water.

R

term / topic	**definition**
receptor	Humans and other living organisms potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along contaminant migration pathways.
redevelopment plan	Plan for any new construction(s) on a site or an area that has pre-existing uses.
remediated site	A site where remediation and post remediation measures have been implemented and there is no residual contamination.
remediation	The doing of any works, or carrying out of any operations or taking of any steps in relation to a polluted site for the purpose of (a) identifying or investigating or preventing or minimising or remedying or mitigating the adverse effects by reason of which polluted site is such site; (b) restoring the quality of environment, flora and fauna at the site to an acceptable level; and includes making of subsequent inspections from time to time for the purpose of keeping under review the condition of the site in question, in the manner prescribed.
remediation design	A technical design for remedial action at the site included in a Detailed Project Report.
remediation goal	*see remediation objective*
remediation objective	Generic term for any objective, including those related to technical (for example risk reduction, residual contamination concentrations or engineering performance), administrative and legal requirements.
remediation option	A means of reducing or controlling the risks associated with a particular source-pathway-receptor combination to a defined level.
remediation requirement	Preset conditions that need to be met before a remediation can be implemented as planned.
remediation target	*see remediation objective*
remediation technique	Physical tools and solutions that can be implemented to eliminate or reduce the presence or negative effects of contaminations in soil or groundwater.

residual contamination	After completion of remediation and post remediation measures, contaminants exist in excess of screening level or there may be existing or imminent threat to health, safety, welfare, comfort or life of human beings, other living species, water quality or the environment in general or to property, that may be mitigated or eliminated with land use and site activity restrictions.
resources	Commodities such as food, water, sand, agriculture land.
Response level	Generic concentrations of hazardous substances in soil and sediments at or above which it is very likely there is threat to human health or the environment, that may be imminent. At or above this level some form of response is required to provide an adequate level of safety to protect public health and/or the environment.
restricted site	A site where remediation and post remediation measures have been implemented and there is residual contamination requiring land use and site activity restrictions.
risk	A combination of the probability, or frequency of occurrence of a defined threat and the magnitude of the consequences of the occurrence related to combinations of Source, Pathway and Receptor.
risk assessment	The process of identifying, assessing and evaluating the risks that may be associated with a threat to human health and/or the environment at a contaminated site. Risk assessment can be carried out by a qualitative identification of potential risks or by calculation of dispersion and exposure.

S

term / topic	**definition**
safety	Freedom from unacceptable risk of harm (during assessment or remediation activities).
sample	Portion of material (soil, groundwater, sediment or surface water) selected from a larger quantity of material.
sample protocol	Technical guidance for the field team in order to ensure quality of sampling, ensure uniformity and to allow for effective assessment of fieldwork quality.
sampling strategy	Arrangement by which a sampling protocol is to be conducted.
sampling technique	All appropriate procedures and sampling devices to obtain and describe samples of soil, groundwater, sediment or surface water, either in the field or during transportation and in laboratory.
Screening level	Generic concentrations of hazardous substances in soil and sediments, groundwater and surface water at or below which potential risks to human health or the environment are not likely to occur and where no further investigation and assessment is needed. These Screening levels are distinguished for land use.
secondary source	Contaminations found in the soil after having been transported from a primary source. E.g. DNAPL layer found at the bottom of a aquifer
sediment	Soils and their parent material beneath the surface water body.
selection remediation option	Process of selection of the most favourable remediation option using certain selection criteria.
sensitive use	Use of land or surface water which is determining the risks for human health and/or the environment.
site	Any area, place, premise, establishment, land and related structures including well, pit, pond, lagoon, landfill, groundwater, sediments, building, structure, pipeline and container and any facility, factory, industry, operation, process or equipment located over such area.
site assessment	Investigation on the content, extent, delineation or risks of a (probably) contaminated site.
site inspection	Inventory and mapping of a probably contaminated site

Site Reuse	Local government shall designate the site use as per the remediation plan and handover the land for use.
site specific remediation target level	A preset target level that facilitates a specified predefined use of a single site.
soil	Upper layer of the Earth's crust transformed by weathering and physical/chemical and biological processes. It is composed of mineral particles, organic matter, water, air and living organisms organized in genetic soil horizons.
soil characterization	Determination of relevant physical, chemical and biological properties of the soil.
soil threatening activities	Activities possible causing a soil to get contaminated.
source	Source in relation to a contaminant means the location from which a contaminant has entered or may enter the environment and the soil, water, sediments that have been contaminated at the point of entry of the contaminant but excludes contamination through migration. (A primary source, such as a location at which drums have leaked onto surface soils, may produce a secondary source, such as contaminated soils; sources may hence be primary or secondary.)
spreading	*see migration*
stakeholder	person or organization who is affected by the effects of a contaminated site or has interest in the assessment and remediation activities at the site
stratigraphy	The order and relative position of geological strata (layers) and their relationship to the geological timescale.
substance	Any chemical element or chemical compound.
surface water	All water at the surface, including lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, wetlands, inlets, canals, oceans within the relevant territorial limits and all other bodies, natural or artificial, inland or coastal, fresh or salt.

T

term / topic	**definition**
target level / target values	A preset level of concentration of a specific contaminant to be achieved when implementing a remediation option.
temporary safety measures	Measures for preventing unacceptable risks pending final remedial measures.
tendering process	Development and implementation of bidding documents for outsourcing assessment activities and/or (post) remediation works.
threats to human health and/or the environment	The situation in which existing or imminent negative impact on human beings and or the environment can occur due to exposure to constituents present at a contaminated site.
topography	The arrangement of the natural and artificial physical features of an area.
toxic and hazardous substances	Substances/constituents as per the ‘Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008’.
tracers	(natural or injected) Matter carried by water which will give information concerning the direction and/or velocity of the water as well as potential contaminants which could be transported by the water.
TSDF	Treatment, Storage and Disposal Facility.
Typology	The taxonomic classification of characteristics found in contaminated sites, based on a set of common characteristics of sites (see Annex of this Glossary for extended explanation of Typology of contaminated sites).

V

term / topic	definition
verification	The process of demonstrating that the risk/threats has/have been reduced to meet (post) remediation criteria and objectives.

W

term / topic	definition
water body	A body of water forming a physiographical feature, for example a sea or a reservoir.

Annex to the Glossary

Explanation of Typology of contaminated sites

1 Introduction

The typology of contaminated sites offers important elements when developing a site assessment strategy and remediation options in a manageable way. These elements are activities leading to contamination, geometry and type of contamination. Combined with site specific information on chemical substances and soil characteristics this typology is useful to get insight in realistic remediation options to facilitate the process of remediation option appraisal.

2 Typology

Table T1 presents an overview of the typology, by showing all activities leading to contaminated soil and types of spreading. These activities are regardless of the party causing the contamination. E.g. liquid phase contaminations are not necessary focused only to industrial activities. On the other hand it is expected that most of this type of contaminations can be found in industrial areas. The following main types of contaminated sites are distinguished using this approach:

Source related:
- Type S1: Land bound solid phase contamination;
- Type S2: Water bound sediments solid phase contamination;
- Type L: Land bound liquid phase contamination. The source of this type of contaminations is connected to human activities or infrastructure.

Pathway related:
- Type P1: NAPL contaminants in soil (Non Aqueous Phase Liquids);
- Type P2: Groundwater contaminations.

Note 1: Although elements in the typology are based on the ‘source-pathway-receptor’ approach, it is not primary ‘receptor’ (risk) based. The typology is not based on risks (risks to human health, ecological risks, spreading or vaporizing). This is because site assessment and soil remediation options appraisal, for which this typology is developed, is not limited to the assessment of unacceptable risks, but needs to give insight in a contaminated site as a whole.

Note 2: depending on a specific situation:
- a combination of these types may be found on one site. Example: a land bound storage of Chromium containing hazardous waste (type S1), leaching Chromium to groundwater and leading to a contaminated groundwater plume (type P2). This combination of types on one single site could result in multiple site assessment strategies and multiple remedial options, each assessing the different types of contaminants (both the site assessment and remediation approach can be combined for practical reasons);
- multiple sites can form a cluster of contaminated sites of a specific type or combination of types. A combination of sites of a specific type in a single cluster or a combination of types on a single site can be recognized. These situations could be indicated as a “cluster-site” with a wide variety of scales. In general, the applicability of remediation techniques will not depend on this setting, but correct balancing of remediation techniques per type of site in a cluster will lead stakeholders to the best applicable remediation option.

Note 3: Both in type L as in type P1 liquid phase contaminants are involved. Type P1 is distinguished from type L by the specific type of contaminant, Non-Aqueous Phase Liquids (NAPL’s), which have a characteristic spreading pattern on or in the groundwater aquifer. This characteristic leads to different site assessment strategies, spreading mechanisms, risk profiles and remediation approaches for type P1 sites, as compared to type L sites. A type L site may, due to further spreading of the contaminant plume, develop over time into a type P1 site.

The main types listed above are based on normative characteristics, which play a role in determining the basics for remediation options. Side characteristics may do so as well, but their influence will in certain cases be restricted to the finer points (mostly technical details) in the selection of remediation options or to the planning or implementation of remediation actions. Thus subtypes come into perspective when remediation option appraisal is going into the second step of option appraisal, the detailed engineering phase. In this detailed engineering phase aspects have to be included related to contaminant specific specifications of remediation techniques, assessment of specific social aspects of the remediation actions or site use specific technical requirements.
Case example. The first step of a site specific remediation option appraisal, based on normative characteristics only, has shown that the remediation should be implemented within a period of less than two months and should result in a removal of all contaminants. In this case only then the site will meet the specific needs for planned reconstruction works. At this point it is already clear that only excavating techniques will be applicable, rendering the assessment of in situ techniques obsolete. This saves gathering and analysing detailed information on the performance of these techniques (e.g. contaminant related performance of in situ techniques) as this will not meet any purpose.

Subtypes can be distinguished based on the following secondary criteria:

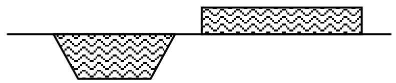
- **Type S1 and L** related subtypes are defined, based on the activity causing the contamination. HW-Schedule I (listing processes generating hazardous wastes) may help to focus on possible activities.
  In Table T1 these subtypes are coded ‘a’ through ‘f’ (type S) and ‘a’ through ‘d´ (type L).
  These subtypes are distinguished to support the site assessment.

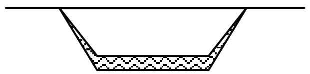
- **Type P1** related subtypes are defined, based on the bulk density of a NAPL (non aqueous phase liquids, dense and light).
  In Table T1 these subtypes are coded ‘a’ and ‘b’ (type P1).
  These subtypes are distinguished to support the site assessment.

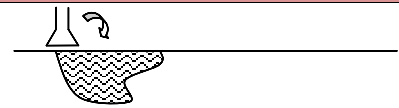
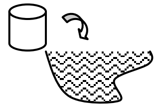
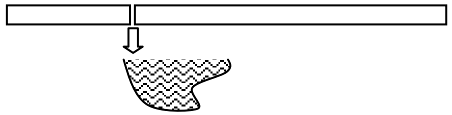
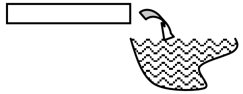
The typology is aimed to support the remediation options appraisal. Some examples to illustrate this point. A site assessment plan for a S1-f type contaminated site (deposition by flooding or washing) will focus on the boundaries of the flooded areas of a river system, easily recognizable on maps or areal pictures. Once the pattern of flooding is known an extensive sampling plan can be carried out to validate the flooding pattern and to validate the hypothesis on the spreading of the contamination with field data. By contrast, a site assessment plan for a S1-c type of contaminated site (storage of contaminated material) will focus on a relatively small area where human activities such as incineration have taken place.

The total volume of the removal of contaminated material, which accounts for the major part of remediation costs, will be smaller for a S1-e type of contaminated site (atmospheric deposition) than for a S1-a type (soil mixed with contaminated material). Therefore, it is more likely that the best applicable remediation option on a S1-e type site will be a complete removal of all contaminants, where for a S1-a type site a capping option is more likely to come into perspective.

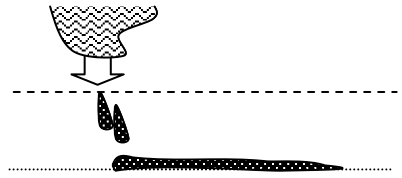
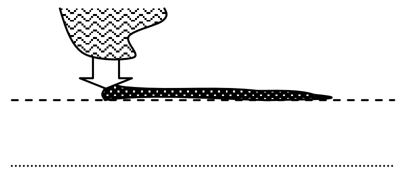
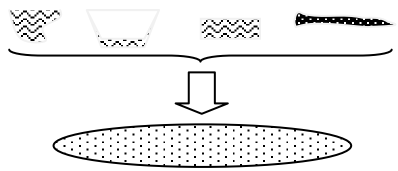
Table T1 Typology

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
S-1	Solid phase contamination (land bound site)		
S1-a *	Mixing the soil with contaminated material or materials containing contamination, not including agricultural activities.	Well defined body below surface level defined by boundaries of soil where soil is mixed with contaminants.	
S1-b **	Embankment, filling of pits or depressions, filling of surface waters with contaminated material or materials containing contamination.	Well defined body of non-mixed contaminants . E.g. storage of tailings.	
S1-c **	(Bulk) storage of contaminated material or materials containing contamination. (Industrial) activities in which contaminated solids are used. 'Leftovers' of incineration and burning of material.	Irregular shaped layer of contaminated material, recognizable as such. The shape of the contaminated site is related to the activity leading to the contamination	
S1-d *	Adding material containing contamination through agricultural activities (e.g. pesticides, fertilizers or additives to animal feed).	Agricultural site bound contaminations found up to a depth to which the soil is treated by ploughs and other agricultural tools.	
S1-e *	Atmospheric deposition (roads, railway, industries) of emissions or windblown dust.	Thin layered contaminations found over large areas with the highest concentrations close to the source following the prevailing wind direction.	
S1-f *	Deposition by flooding or washing.	Contaminations found in areas flooded by water systems or in downstream areas of flooding areas. The shape of the contaminated site is	

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
		determined by the flooding of flow of a water system.	
S-2	Solid phase contaminations (water bound site)		
S-2 **	Contaminated open water sediments.	Solid phase contaminants sedimented from surface water. The shape of the contaminates site corresponds to the shape of the water system itself. Contaminants may be bound to clay or organic compounds of sediments.	

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
L-1	Liquid phase contaminations		
L1-a *	(Business) activities involving fluids e.g. solvents, lubricants, paint, etc.	Liquid contamination in soil situated near a potential source of the contamination.	
L1-b *	Storage of liquids that contain contaminations in tanks or barrels (either storage on surface or subsurface).	Liquid contamination in soil situated at any place at a liquids storage site.	
L1-c *	Transfer and transport of fluids through linear infrastructure. Weak points are couplings, pressure regulators, valves, breakpoints and the passage through foundations / buildings.	Liquid contamination in soil situated at any place along a transport piping system or drains.	
L1-d	Spills or leaks of liquids. (either on surface or in rivers/lakes) *Note. Possibly leading to type S2 or P2.*	Liquid contamination in soil situated at the end of a transport piping or drain system.	

*) caused by multiple sources or situation where source cannot be attributed.

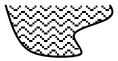
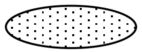
Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
P-1	Liquid phase related		
P1-a	Dense Non-Aqueous Phase Liquid (DNAPL [a])) in permeable soil. (bulk density > water)	Spreading of liquids due to gravity flow resulting in a characteristic spreading pattern. The DNAPL's laying of the botom of an aquiffer can result in a 'secondary source' of spreading of type P-2)	
P1-b	Light Non-Aqueous Phase Liquid (LNAPL [b])) in permeable soil. (bulk density < water)	Spreading of liquids in a characteristic spreading pattern of floating layers. The LNAPL's laying at the top of a water table can result in a 'secondary source' of spreading of type P-2)	
P-2	Leached or dissolved contaminants		
P-2	Groundwater contamination	Due to spreading of leachate or mobile dissolved contaminants in a permeable soil	

a) *A dense non-aqueous phase liquid or DNAPL is a liquid that is both denser than water and is immiscible in or does not dissolve in water. The term DNAPL is used primarily by environmental engineers and hydro geologists to describe contaminants in groundwater, surface water and sediments. DNAPLs tend to sink below the water table when spilled in significant quantities and only stop when they reach impermeable bedrock. Their penetration into an aquifer makes them difficult to locate and remediate. Examples of materials that are DNAPLs when spilled include chlorinated solvents or creosote.*

b) *Light Non-Aqueous Phase Liquid (LNAPL) is a groundwater contaminant that is not soluble and has a lower bulk density than water, which is the opposite of DNAPL. Once LNAPL infiltrates through the soil, it will stop at the water table. The effort to locate and remove*

LNAPL is relatively cheaper and easier than DNAPL because LNAPL will float on top of the water in the underground water table. Examples of LNAPLs are gasoline and other hydrocarbons.

Table T2 Key to icons in table T1

Icon	Key
	Solid waste or solid waste mixed with soil (all solid phase). Varying in shape, thickness and extent, depending on local conditions.
- - - - - - - - - - - - - - -	Groundwater table Base of aquifer / top of impermeable layer.
	Liquid waste. Pure or mixed with soil.
	Leaching / spreading of contaminants to soil / groundwater. Depending on permeability of the soil.
	Contaminated groundwater plume. Depending on permeability of the soil.
	DNALP or LNAPL.
	Spill / leakage.
	Not soil related human activity / construction e.g. industrial process, storage, bulk transfer.

Colophon

Colophon

Context
The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, has taken up the Capacity Building for Industrial Pollution Management Project (CBIPMP) with the assistance of the World Bank. The intention is to develop a National Programme for Rehabilitation of Polluted Sites (NPRPS). Details of this project are available on the MoEF&CC website (http://moef.nic.in/sites/default/files/cbipmp/index.htm).

As a part of the CBIPMP project, MoEF&CC in March 2012 commissioned a consortium led by Grontmij Nederland BV (Netherlands) and otherwise comprising of Shah Technical Consultants Pvt.Ltd. (India), Technochem Agencies Pvt.Ltd. (India) and Indus Technologies Netherlands BV (Netherlands and India) to undertake a consultancy assignment for “Development of Methodologies for National Programme for Rehabilitation of Polluted Sites”.

The key objective of this assignment was to develop methodologies for the implementation of remediation projects in India by government and non-government agencies under the NPRPS. These methodologies mainly cover [i] the process for selecting and implementing preferred remediation options and [ii] the technical guidelines and standards that can be applied.

Development of the document
The Grontmij consortium has executed the assignment between April 2012 and December 2015, with its team of Dutch, Indian and international experts. The assignment comprised:

- a large number of desk studies on a wide variety of topics;
- review of national and international standards, practices, experience and learning;
- field visits to several contaminated sites in India;
- extensive discussions with several stakeholders, including CPCB, SPCBs, individual technical experts, academics and field staff in charge of the sites;
- discussions with experts outside the consortium;
- evaluation of previous reports, evaluation and incorporation of field tests conducted in the past and in parallel by other assignments;
- stakeholder meetings to gain input on draft reports;
- discussions with the Technical Expert Panel and supervising experts from the Ministry and World Bank.

In performing the study, a number of specific tasks have been carried out as mandated by the Terms of Reference of the assignment. For each task, a detailed report has been prepared by the Grontmij consortium. This Guidance document consists of three Volumes.

Key authors of this document include: Arthur de Groof, Paul Oude Boerrigter, Rob Heijer, Paul Verhaagen, Ravi Jambagi, Sukla Sen, Hemant Rane and Deepak Deshpande.

Initial use
The Guidance document provides MoEF&CC, agencies such as CPCB and SPCBs and various other stakeholders with a comprehensive reference manual to further develop the NPRPS effectively, educate and train key technical staff and to enable MoEF&CC to initiate necessary steps towards remediation of sites, whether identified at the time of publication or as yet to be identified.

National Program for Rehabilitation of Polluted Sites in India

Guidance document for assessment and remediation of contaminated sites in India

Volume II – Standards and checklists

1st Edition, December 2015

Ministry of Environment, Forest and Climate Change
Government of India

Volume II
Introduction and contents

Introduction to Volume II of the Guidance document for assessment and remediation of contaminated sites in India

This document encloses Volume II of the Guidance document for assessment and remediation of contaminated sites in India.
In this Guidance document the technical aspects of the entire process of intervention in a contaminated site, from its earliest identification to post remediation measures, is described in a sequence of fourteen distinct Steps. This set of Steps covers all activities that are performed in dealing with such a site. Wherever applicable, this Guidance document refers to these fourteen Steps. The same Steps, with identical descriptions, are also used in correlation with the non technical aspects, i.e. legal, financial and institutional, of dealing with polluted sites.

The fourteen Steps are visualised in figure II.1 below.

Figure II.1 The fourteen Steps in the site assessment and remediation process

Identification	Planning	Implementation	Post remediation
• Step 1: Identification of probably contaminated sites • Step 2: Preliminary investigation • Step 3: Notification of polluted site • Step 4: Priority list addition	• Step 5: Remediation investigation • Step 6: Remediation Design, DPR • Step 7: DPR approval and financing	• Step 8: Implementation of remediation • Step 9: Approval of remediation completion	• Step 10: Post remediation plan • Step 11: Post remediation action • Step 12: Cost recovery • Step 13: Priority list deletion • Step 14: Site reuse

This Guidance document is organised as a set of documents, arranged in three Volumes:

Volume I	Methodologies and guidance
Volume II	Standards and checklists
Volume III	Tools and manuals

Volume I is the core of the Guidance document set. It presents guidance and instructions as to how to perform each of the fourteen Steps in the site assessment and remediation process. The correlation among the Steps is shown, to enable the user to see what happened before the Step he is involved in and what should happen after completion of that Step. Centred around a concise description of actions to perform the Step the user is involved in, the guidance details aspects for an effective performance, like data needed and where these may be found, and control mechanisms. Wherever relevant, the guidance includes references to Volume II and III and to websites and documents. Volume I is set up in such a way that it may be used in capacity building. It also includes an introduction for aimed at decision makers.

This **Volume II** contains reference data in various forms. Engineers dealing with contaminated sites may use Volume II on a day to day basis to refer to data, standards, criteria and checklists. Every one of these is linked by a reference to one or more descriptions of Steps in Volume I. Therefore this Volume II document should be used in conjunction with the other two Volumes.

Volume III contains more extensive data like technical manuals. Examples of manuals presented in Volume III include a Site Inspection Protocol, points of attention for laboratory testing, an overview of available remediation techniques, and methods for the evaluation of remediation options. Like Volume II, Volume III is intended for day to day reference by engineers dealing with contaminated sites.

Contents of Volume II

Volume II

1-a Example petition format for identification of probably contaminated sites

Volume II-1-a
Example petition format for identification of probably contaminated sites

1 Introduction

This information is most relevant for Step 1, Identification of probably contaminated sites. During the data collection information regarding newly recognized probably contaminated sites may be partly derived from petitions, reports, complaints etc. from local or state level agencies, general public and NGOs received by the competent authority. The use of a standardised petition format will improve the completeness and quality of the information necessary for submission of a well-founded petition for which below an example petition format is provided.

2 Example petition format for identification of probably contaminated sites

Example petition format for identification of probably contaminated sites The completed form should be delivered to the nearest office of the competent authority. ***Objective of this petition*** This petition provides the site details and background information related to a probably contaminated site.

Applicant Details

Name of petitioner	
Address	
Email	
Telephone number	

Site Details, (please provide a description where possible)

Relation of the petitioner to the site: Owner of the site, tenant of the site, occupier or resident of the site or nearby site, use of the site for specific purpose, etc.

Site Location and description:
Address or coordinates. Attach a plan, sketch map / drawing with landmark information clearly identifying the site. If not possible describe the surrounding area and distance to notable landmarks, roads, rivers, etc.

Description of the landuse:
Habitation settlement/residential, agricultural land, commercial, industrial, forests, park, water body, waste land, or other (one or multiple types of landuse can be described).

Description of the signs of suspected contamination:
For example: well water that is discoloured or with bad taste or smell; unpleasant smells related to waste material or soil surface; human and animal health problems not related to general diseases or lack of food and water; damaged crops, plants or trees not to be related to lack of water or nutrients; . containers containing suspected chemical substances.

Description of substances involved:
If possible please provide a description on the substances including symbols and / or labels on containers, chemical name (common name), solid/liquid/gas form, type of smell and colour.

Description of possible cause of the contamination: Presence of (former or existing) industry buildings, materials stockpiles, industrial process equipment, storage tanks, broken pipelines, illegal dumping etc.

Description of previous involvement of local or regional governmental agencies regarding contamination of the site (if applicable):

Date of receipt of the petition:
Reference number:

Volume II

1-b Checklist relevant data for identification of probably contaminated sites

Volume II-1-b
Checklist relevant data for identification of probably contaminated sites

1 Introduction

This information is most relevant for Step 1, Identification of probably contaminated sites. During the data review information regarding new probably contaminated sites may be partly derived from petitions, reports, complaints etc. from local, state level agencies, government agencies, general public and NGOs received by the competent authority or they may be collected by reviewing registers and plans. The data necessary for identification of probably contaminated sites are described in the below checklist.

2 Checklist relevant data for identification of probably contaminated sites

No.	Topic	Explanation	Data Provider / Source	Obligatory	Status	Comments
	Administrative elements					
1.0	State name		Provided by source	Yes		
1.2	Site name		Provided by source	Yes		
1.3	Address	Street, Street number, Postal code, City	Provided by source	Yes		
1.4.1 1.4.2 1.4.3	GPS coordinates /and elevation:	Latitude, longitude and altitude in center of the site entered as decimal	Provided by source or established based on address	Prefereably		
1.5.1 1.5.2 1.5.3	Land use	Current land use Previous land use Future land use	Provided by source or established based on address or site visit	Prefereably		
1.6.1 1.6.2 1.6.3	Owner	current owner previous owner contact with owner	Provided by source			
	Essential information for decision on step 1					
1.12	Industry type, which has caused contamination	Selection from a non-exhaustive list of industries	Provided by source and assessed according to list	At least one of item 1.12, 2.2, 2.3, 2.4 and 2.6 shall be stated		
2.2	Type of contamination according to definition from MoEF	Effluent, Air, Municipal Solid Waste, Bio-Medical Waste, Hazardous Waste, Ship Break Waste or Any other.	Provided by source and assessed according to list			
2.3	"Industrial processes" which caused the contamination	According to Schedule I – Hazardous Wastes Rules, 2008	Provided by source and assessed according to list			
2.4	Type of hazardous waste	According to Schedule I – Hazardous Wastes Rules, 2008	Provided by source and assessed according to list			
2.6	Contaminants of concern - CoC - (chemical name(s))	Multiple contaminated can be selected	Provided by source and assessed according to the chemicals listed in the Screening Levels and Response Levels			

	Useful information but not essential in step 1					
3.1	Geology at the site (is the groundwater geologically protected?)	Broad description of the typical stratigraphical sequences from topsoil to deepest acquifer	Provided by source or search on website of Central Groundwater Board, Ministry of Water Resources: http://cgwb.gov.in/	Prefereably		
3.4	Is the site within a groundwater recharge zone?	Area with drinking water interest: - Potable water supply; - Acquifer potential - Minor acquifer/Non potable water	Provided by source or search on website of Central Groundwater Board, Ministry of Water Resources: http://cgwb.gov.in/	Prefereably		
3.5.1 3.5.2	Drinking water intake; distance to nearest well and number of wells within 1 km of site	Private wells Public wells	Provided by source or search on website of Central Groundwater Board, Ministry of Water Resources: http://cgwb.gov.in/	Prefereably		
4.2	Name and distance to nearest surface water body (m)			Prefereably		
4.3	Type of Surface Water Body	Pond, Small lake, Large lake, Small river/stream, Large river, Wetland or Other		Prefereably		
4.4	Any sensitive use of surface water?	Drinking water, Irrigation, Use in commercial food production, Water recreational area, Fishing or Other		Prefereably		
4.5	Distance to Sensitive Ecological areas (m)	E.g. reserves, wetland		Prefereably		
5.2.3	Approximated Population within 1 km from the site			Prefereably		
12.1	Name of institution / source which has identified the site as 'probably contaminated'	Point out institution(s) and contact person	Provided by source	Yes		
-	Reason why the site is considered as 'probably contaminated'		Provided by source	Yes		

Explanatory Notes:
No.: the numbers relate to the topics in the database of contaminated sites
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II

2.1-a Checklist prequalification for site investigation

Volume II-2.1-a
Checklist prequalification for site investigation including ToR

1 Introduction

This information is most relevant for Step 2, Preliminary investigation, Step 5, Remediation investigation and Step 6, Remediation design, DPR. The investigation activities is usually commissioned to an independent third party investigator, typically a specialized organization (agency, research institute, consultants, contractors and laboratories), where teams of specialists are involved in assessment and remediation projects. This checklist is also useful for Task 8.3, Execution, supervision and verification of remediation works.

The client who contracts out this assignment may be a private person, private organization or the local, State or Central authority. This checklist provides support for the client in the selection of a specialized agency. To ensure a good quality investigation, it is vital that this third party can demonstrate the expertise, skills and compliance relevant for the assignment. Where available, it is preferable if this is supported by relevant accreditations.

At the outset, it is very important that the client provides clear Terms of Reference (ToR), which should at least include the objectives of the investigation, the required output and the possible constraints. Without a clear ToR the third party may interpret the situation differently resulting in the proposed activities not leading to the required output. Furthermore, in case more than one party is requested to tender an offer, an unclear ToR can lead to differences that render a fair comparison impossible. If the client is a private organization it may be advisable to contact the competent authority for assistance.

2 Checklist for prequalification for site investigation

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main aim of the appointment	
Date of recording	
Recording official	

Prequalification criteria for selection of the specialized organization (aspects marked * may only be relevant for projects with an estimated cost threshold value of for remediation of 10.000.000 Rupee);	**Status**	**Comments**
Information about the Firm: Firm's Background and registration Financial background* such as		

- tax clearance by financial authority (have all taxes been paid during the last 3 years? - ... other examples? Type of firm – Pvt. Ltd..- Proprietary – Partnership Work experience Professional liability insurance		
Technical capability: Firm's work experience Field technique equipment Accredited laboratory (refer explanation below) Laboratory equipments Labours (skilled & unskilled) Staff experience in similar projects		
Management capability: Cost control Schedule / time Control Quality Management System* Quality assurance* Number of technical and non-technical staff Experience in social aspects regarding investigation of sites for environmental reasons.		
Past experience: Scale of projects completed Type of projects completed Experience in local area Five projects of similar type completed Time overruns in past projects* Cost overruns in past projects* Quality achieved in past project*		
Health and safety policy: Safety management system Accidents in past projects Insurance of personnel		
Use of Information Technology & Services: Project Management Software Personnel knowledge in IT / Software Level of Technology		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Accreditation Standards for Laboratory
For field work and laboratory testing quality assurance can substantially improve the quality of the deliverables. In India, for a great number of laboratory activities accreditation schemes have been implemented. It may be anticipated that in future similar schemes may be implemented for field work and for chemical analysis of soil, sediment and groundwater samples.

Accreditation is considered as the first essential step for facilitating mutual acceptance of test results and measurement data. Confidence in accreditation is obtained by a transparent system of control over the accredited laboratories and an assurance given by the accreditation body that the accredited laboratory fulfils the accreditation criteria at all times. Accredited laboratories can objectively state conformance of specified products or services to specified requirements.

The Government of India has authorized NABL as the accreditation body for testing and calibration laboratories. NABL is a registered society under the Societies Registration Act 1860. It operates as an autonomous body under the aegis of in the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India. NABL has been established with the objective of providing Government, Industry Associations and Industry in general with a scheme of laboratory accreditation which involves third-party assessment of the technical competence of testing and calibration laboratories.

In the current global scenario an essential pre-requisite of trade is that any product or service accepted formally in one economy must also be free to circulate in other economies without having to undergo extensive re-testing. To ensure that this principle is upheld accreditations granted by foreign accreditation bodies are also valid in India, provided the granting body has signed the ILAC MRA (International Laboratory Accreditation Co-operation Mutual Recognition Agreement) for the relevant accreditation standard.

Preferably, the laboratory testing of samples from contaminated sites should be carried out by laboratories working under internationally recognized accreditation standards. The laboratory accreditation services to testing and calibration laboratories are provided in accordance with ISO/ IEC 17025: 2005 ‘General Requirements for the Competence of Testing and Calibration Laboratories’.

NABL Accreditation is currently given in dozens of fields and disciplines or groups. The criteria for standard laboratories for relevant fields for contaminated sites can be found in the following links:

- NABL General information brochure, NABL-100 document, 201206291037-NABL-100-doc.pdf
- NABL specific guidelines for chemical testing laboratories, NABL-103 document, 201206281205-NABL-103-doc.pdf

3 Elements for Terms of Reference for site assessment

3.1 Introduction
This section presents the elements that should be included in any Terms of Reference for effective completion of a number of activities in the site assessment process. The elements describing the Scope of Work, which are specific to the activity at hand, are preceded by a list of generic elements that should be included in any ToR, irrespective of the activity it is designed for.

3.2 Generic elements
The Terms of Reference should include at least the following elements:
- Location of site and explanation of the situation of the site with regard to contamination of soil, sediment, groundwater or surface water;
- Summary of activities regarding assessment and/or remediation which already have been carried out;
- Objective of the project;
- Phases of the project (if applicable)
- Scope of Work, a detailed description of activities (according to the 14 step framework. See Annexure 4 for that framework);
- Expected outputs of the project (reports, drawings, etc.);
- Timeline;
- Procedure for review of draft and final reports;
- Qualifications for agency and project team;
- Expected communication with client and facilities to be provided by client;
- Financial-economic conditions for the project.

3.3 Scope of Work elements

3.3.1 Introduction
In a Terms of Reference for a site assessment the Scope of Work provides a detailed description of activities to be performed. Below, we present the Scope of Work elements to be included in Terms of Reference for the following site assessment activities (position in 14 step framework is indicated between brackets):
- Preliminary site investigation (Step 2, Task 2.2);
- Detailed site investigation (Step 5, Task 5.1);
- Risk Assessment (Step 5, Task 5.2);
- Setting remediation objectives and requirements (Step 5, Task 5.3), Development of remediation options (Step 5, Task 5.4), and Selection remediation option (Task 5, Step 5.5);
- Remediation design, DPR (Step 6).

3.3.2 Preliminary site investigation (Step 2, Task 2.2)
Within this task the following activities are performed:
- Design of the investigation and testing strategy
- Fieldwork and laboratory testing
- Comparison of the test results with standards
- The above mentioned activities are carried out leading to a report including following sections:

Site identification: site name, address, owner, coordinates;

Site description
- History of site use (ownership, operators, users, raw materials, waste related activities, permits, etc.)
- Environs of the site (land use, groundwater use, use of water bodies, estimated number of residents or onsite workers, estimated distances to sensitive use, etc.)

- Climate data (precipitation, temperature and derived information/estimated parameters such as evapo-transpiration and groundwater recharge rate estimated from this data
- Geology and hydrogeology (stratigraphy, aquifers, depth and permeability of subsurface layers, possible karst features, etc.)
- Hydrology and surface water (distance from site to water bodies, migration paths of rainfall to surface water, drainage, flooding patterns)
- Results from previous investigations or incidental data
- Result of site inspection
- Hypothesis on type and characteristics of the contamination
- Features / targets for investigation

Site inspection including:
- Identification of previous and current land use pattern of the site
- Current sources of hazardous waste generation contributing to the pollution of the site and disposal practices in the influence area.
- Site photographs
- Identification of parameters causing immediate threat to the ecology and environment.
- Discussion with local people and other informed people, district administration, municipal and regulatory authorities, NGOS, etc.
- Selection of the available observation wells (Bore Well) in the watershed covering the site, for monitoring water level and quality monitoring at appropriate locations, & Inventory details like total depth of the well, Water column; Frequency of sampling (Pre monsoon/ Post monsoon)

Investigation Strategy
- Draft Conceptual Site Model
- Screening and sampling strategy
- Fieldwork screening methods
- Exploratory hole / sample location pattern (grid or targeted) and numbers of samples (soil, sediment and groundwater) , including benchmark / background samples
- Use of composite and single samples
- Parameters for laboratory testing and chemical analysis methods / detection limits
- Applied method for quality control (QA/QC)

Fieldwork results, interpretation and reporting including
- Site conditions during fieldwork (e.g. dates, weather conditions, access to locations, etc.)
- Visual / olfactory evidence of contamination
- Results of screening techniques (if applied)
- Description of ground conditions and subsurface structure (borehole / exploratory hole log description)
- Selection of samples to be tested
- Laboratory test results
- Comparison of laboratory test results to standards (Screening levels and Response levels)
- Does the site meet the definition of ‘Contaminated Site’?
- Recommendation for:
  - further investigation (yes/no);
  - notification as contaminated site (yes/no) leading to prioritisation and remediation investigation;
  - temporary safety measures if in the present situation significant risks to human health or environment are expected.

3.3.3 Detailed site investigation (Step 5, Task 5.1)
Within this task the following activities are performed:
- Development of investigation strategy
- Fieldwork and laboratory testing
- Analysis and interpretation of exploratory data

The above mentioned activities are carried out leading to a report including following sections:

Introduction and background information

- Description of the site (e.g. name, address, site plan and size);
- Reason for the detailed site investigation;
- Summary of the previous investigations at the site;
- Information of the parties involved in the remediation investigation process and allocation of their roles;
- Scope of the investigation;
- Explanation of the structure of the report.

Site situation

- The lay-out on the site (present land use, infrastructure, buildings, use of the surrounding area, included natural features such as lakes, rivers, streams found at least partially within the boundaries of the property) and in the area beyond the site covering the pathway;
- Description of history of the land use and possible causes of the contamination (included constructed features such as, underground storage tanks, lagoons, ditches, sumps within buildings, and waste storage areas);
- Typology of the contaminated site;
- Geology, geohydrology and soil structure and ground conditions of the site in case of contaminated soil and groundwater (depth of groundwater, thickness of aquifers, seasonal groundwater fluctuations; the lithology and vertical permeability of the unsaturated zone; the stratigraphy, structure, geometry, porosity, hydraulic conductivity, storage properties, transmissivity, and groundwater flow direction of the saturated zone).
- If monitoring or drinking water wells have been installed: review of the monitoring results; include data why and when a well was installed and by whom and technical data (depth, filter length, monitoring data, sample and lab methods)
- Soil survey information at a scale of 1:20 000 or larger; on-site map and appropriate cross-sections showing soil types, soil depth and other soil parameters that may be related to location and extent of contaminants;
- Climatic conditions (precipitation, seasonal variations, estimated infiltration rates);
- Morphological and hydraulic aspects including e.g. seasonal variations in water level and floods and and areas affected by floods to estimate the impact of contaminated sediments.

Investigation strategy

- The conceptual site model (CSM) with the combinations of source-pathway-receptor) of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density);
- Data gaps in the CSM and points for investigation;
- Screening and sampling technical equipment;
- Sampling rationale and design (media, locations, pattern and depth of samples), including background samples;
- Number of samples;
- Screening of observations wells or necessity for drilling new wells;
- Methods for establishing stratigraphy and characteristics of subsurface layers;
- Analytical test parameters / determinants required.

Fieldwork and laboratory testing

- Description of executed activities;
- Site conditions during fieldwork (e.g. dates, weather conditions, access to locations, etc.)
- Visual / olfactory evidence of contamination
- Results of screening techniques (if applied)
- Description of ground conditions and subsurface structure (borehole / exploratory hole log description) or water body;
- Selection of samples to be tested;
- Laboratory test results;

- Quality assurance and quality control;
- Possible deviations from sample plan and reasons involved.

Analysis and interpretation of exploratory data
- Comparison of laboratory test results to standards (Screening levels and Response levels);
- Description of situation of the contamination in the various media (soil, groundwater, sediment, surface water, air, biota) including depth and extent of contamination and including estimated quantity of polluted media;
- Implications of contamination, soil structure and general physical, chemical, ecological and spatial site conditions for remediation options;
- Development of groundwater flow, surface water flow, and mass transport models. (if required);
- (Seasonal) contour maps of groundwater flow and explanation of estimated groundwater processes;
- Possible influence of seasonal climatological situation on groundwater and surface water;
- Contour maps and cross-sections to show spatial distribution of contaminants; graphical displays that present the available data in their spatial context; sample values for data on maps or cross-sections; colours; grey scales, or symbols to high-light the locations of the highest sample values;
- Updated Conceptual Site Model, identifying sources, pathways and receptors.

Conclusions and recommendation
- Conclusions on the scope and objectives of the investigation with clear indication of known data gaps and possible uncertainties;
- Recommendations for
  - further investigation;
  - temporary safety measures if in the present situation significant risks to human health or environment are expected. This may include monitoring of a contaminated plume in groundwater.

Annexes
- Topographical map of area with location of the site
- Detailed site survey plan with location of sampling points
- Methods of fieldwork and laboratory testing
- Borehole / exploratory excavation logs with explanation codes
- Relevant screening and response levels
- Laboratory reports
- Calculations or modelling results and explanation characteristics of the model used
- Maps indicating contamination of soil, sediment and groundwater
- Background literature and sources
- Photographic record

3.3.4 Risk Assessment (Step 5, Task 5.2)
Within this task the following activities are performed:
- Assess contaminant concentration levels;
- Identify applicable source-pathway-receptor-combinations for human health;
- Perform a generic quantitative risk assessment for human health;
- If necessary, perform a more detailed quantitative risk assessment for human health;
- If necessary, perform a risk assessment for the environment;
- The above mentioned activities are carried out leading to a report including following sections:

Introduction and background information
- Description of the site (e.g. name, owner, address, site plan and size, GPS-coordinates);
- Summary of the previous investigations at the site;
- Information of the parties involved in the assessment and remediation process and allocation of their roles;
- Reason for and objectives of risk assessment.

Site situation

- The situation of the contamination at the site (present land use, infrastructure, buildings, use of the surrounding area);
- Description of history of the land use and cause of the contamination;
- Description of area with respect to existing land use, demographic profile, social economic and environmental conditions of the people in receptor areas, flora and fauna;
- Comparison of concentration levels against Screening and Response levels.

Relevant source-pathway-receptor combinations

- The conceptual site model (CSM) with the combinations of source-pathway-receptor of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density);
- Relevant exposure pathways, preferably illustrated with diagram.

Results of generic quantitative risk assessment modelling

- Tool/model used to quantify risks
- Site-specific information used for modelling
  - Representative concentrations in soil, sediment and groundwater
  - Size of contamination in soil (3D)
  - Size of contamination in groundwater (3D)
  - Size of the site (contaminated and not contaminated)
  - Level of groundwater
  - Soil type (%organic matter, % clay, grain size, hard rock)
  - Surface water in the environment
  - Drinking water extension in the environment
  - Groundwater flow direction and estimated speed
  - Use of the contaminated site and the vicinity
  - Establishment of the site (buildings, basements, roads, crops)
  - Receptors on-site and off-site
- Model results and comparison to critical exposure value

Results of detailed quantitative risk assessment

- Reason for detailed quantitative risk assessment
- Collection of additional information (methodology used for obtaining data)
- Data obtained, e.g. contaminants investigated, contaminant concentration levels in the relevant contact media (e.g. air, dust), relevant specific circumstances
- Results

Conclusions and communication

- Clear statement on unacceptable risks identified
- Possible uncertainties and information gaps, necessity for further investigation
- Recommendations for further steps, setting remediation options and development of remediation options

3.3.5 Setting remediation objectives and requirements (Step 5, Task 5.3), Development of remediation options (Step 5, Task 5.4), Selection remediation option (Step 5, Task 5.5)

Within task 5.3 (Setting remediation objectives and requirements) the following activities are performed:

- Establish remediation objectives;
- Establish remediation requirements.

Within task 5.4 (development of remediation options) the following activities are performed:

- Assess the remediation objectives and requirements;
- Identify constraints to remediation;
- Identify applicable remediation techniques;
- Develop applicable remediation options.

Within task 5.5 (selection remediation option) the following activities are performed:

- Compare and appraise remediation options;
- Consult with relevant stakeholders;
- Prepare remediation investigation report, including stakeholder views;
- Review and approval of remediation investigation report and select most favourable remediation option.

The above mentioned activities are carried out leading to a report including following sections:

CSM and risk assessment

- Historical information of the site including subsequent site and groundwater use, industrial processes leading to soil contamination
- Geology
- Geohydrology
- Description of all contaminations (sources) including spreading processes (pathways)
- Description of risks (receptors)

Remediation objectives

- Risks to be remediated
- Objectives of the remediation
- Requirements of the remediation including other activities which are executed simultaneously (redevelopment)
- Stakeholders
- Funds
- Other legislation to be met
- Preconditions to be met with the remediation

Description remediation options

- Technical aspects to achieve the remediation objective an requirements
- Effects on surrounding and counter measures: sound, noise, soil vibration, groundwater drop, traffic hinder (intensity and duration), stability of soil
- Practical aspects of implementation: preparation of / on the site, safety measures
- Measurements / sampling program to verify the progress and final result of the implementation phase
- Communication with stakeholders prior to, during and after the remediation
- Production and/or usage of: energy, soil, air, water and activities or technical measures to dispose of products
- Risks and mitigating measures during implementation: technical, planning, concentration levels
- Legal aspects: permits and legal constraints
- Planning: preparation phase, implementation, extensive phase of in situ techniques, post remediation measures
- Post remediation measures: description of residual contaminations and subsequent technical and management measures necessary to prevent future human and ecological risks and risks of spreading of the contaminations
- Costs: implementation, post remediation phase and risks
- Point for further investigation during DPR or pilot phase

Evaluation of possible remediation options

- Points for evaluations
- Method for evaluations
- Evaluations of options (qualitative or quantitative)
- Selection of most favourable remediation option
- Point for further investigation during DPR or pilot phase

Annexes

- Maps, x-sections, tables technical schemes

3.3.6 Remediation design, DPR (Step 6)

Within this Step the following activities are to be performed:

- Design of the remediation: the technical system for the remediation will be presented. Detailed descriptions and drawings of the remediation measures will be reported.
- Costing and planning of the remediation: all activities are summarized and a costing is provided for each of these activities (volumes, amounts and unit prices). A planning of activities is made indicating the time involved for the activities.
- Environmental and social impact assessment and consultation of stakeholders
- The above mentioned activities are carried out leading to a report including following sections:

Introduction and background information

- Description of the site (e.g. name, owner, address, GPS-coordinates, site plan and size);
- Reason for the remediation;
- Summary of the previous investigations at the site;
- Information of the parties involved in the remediation process and allocation of their roles.

Site situation

- The situation of the contamination at the site (present land use, infrastructure, buildings, use of the surrounding area);
- Description of history of the land use and cause of the contamination;
- Typology of the contaminated site;
- Geology, geohydrology and soil structure and ground conditions of the site in case of contaminated soil and groundwater.
- Morphological and hydraulic aspects in case of contaminated sediments in surface water and seasonal variations in water level;
- The conceptual site model with the combinations of source-pathway-receptor) of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density);

- Remediation approach
- Objective of the remediation related to regulatory requirements and the selected remediation option;
- Combination of the remediation with reconstruction activities at the site, possible impact on planning and results of the remediation measures and description of measures to manage this impact;
- Targets levels of the remediation to be achieved;
- Remediation techniques to be used: technical description;
- Stages in the remediation process (if appropriate);
- Necessity of a pilot testing of the remediation technique.

Detailed description of the remediation process

- Preparation activities:
    - removal of buildings, infrastructure, foundations, tanks in order to achieve access to the contaminated material; if removal is not possible, which working constraints will have to be dealt with;
    - mobilisation of equipment to the site;
    - necessary staff during the remediation;
    - organising the working and storage areas at the site;
    - possible access limitations to parts of the site or the neighbouring area;
    - availability of suitably licensed treatment or disposal capacity off site;
- Overview of the necessary permits and licenses;
- Measures necessary to prevent damage or nuisance (such as dust, odours, noise and dirt on roads) on the site and in the surrounding area (including possible transport of removed waste to a treatment or disposal site);
- Measures to improve sustainability aspects (e.g. reducing energy);
- When excavation of soil or dredging of sediment is part of the remediation strategy:

  - size and contours of the excavation (area and depth);
  - estimated volume of material to be excavated (in-situ and after excavation) and destination of the material (on-site rearranging or off-site treatment or disposal, for which the procedures of HWR-2008 may apply);
  - necessary abstraction of groundwater;
  - in case of dredging sediment: necessary preparation on the water way, lake, river or canal;
  - temporary storage of material in depots;
  - quality of the clean material to be used to replace the removed contaminated material;
- When groundwater abstraction is part of the remediation strategy:
  - Pattern and depth of wells;
  - Volume and planning of the abstraction period;
  - Results model calculations of the groundwater remediation;
  - Method of discharging abstracted water and necessary treatment;
- When in-situ techniques are part of the remediation strategy:
  - Equipment to be installed (indication, pattern and specific location);
  - Maintenance activities during the active phase of the remediation;
- Checkpoints during the remediation process and action levels or other criteria for assessment the intermediate results;
- Possible effects of the remediation measures and mitigating activities to be carried out to minimize these effects;
- Possible uncertainties in the situation (e.g. the delineation of the contamination is not very detailed at one side of the location) and ways of dealing with these risks.
- Planning of the remediation activities (project implementation schedule);
- Programme for supervision and environmental verification;
- Suggestions for sampling, testing and other measurements related to verification (to be elaborated further in a verification plan):
  - what are be the key parameters to verify the success of the progressing remediation;
  - which monitoring equipment should be installed before and during the remediation.
- Expected restrictions to future land use after finalizing the remediation activities;
- Identification of the need for post remediation activities;
- Health and safety aspects during the remediation:
  - possible exposure to contaminated material by skin contact, ingestion or inhalation;
  - necessary measures to prevent these risks (description of these measures to be elaborated in step 8);
  - safety measures regarding equipment and transport.
- Record keeping, use of a log;
- Estimation of costs, with distinction between costs for installing equipment, short term measures and costs for long term remediation and maintenance. Sometime an analysis of risks and variation of the costs;
- Insurance;
- Communication aspects in the process of implementation of the remediation. These communication aspects are related to restrictions and nuisance during the remediation and the possible restriction for land use in the final situation. Relevant stakeholders for the communication should be indicated;
- Maps, drawings, calculations must be added as annexed to the remediation design report.

Content of verification plan

This Section presents a generic checklist for a verification plan, being part of the Detailed Project Report. In this verification plan the activities are described for verifying the results of the remediation.

Supervision and environmental verification

- Description of the tasks of the supervision and environmental verification of remediation works;
- Possible response actions to deal with uncertainties;
- Critical points in the remediation process where the progress should be assessed, a list of critical points during the remediation is given below (examples are the moment where an excavation; has reached its ultimate boundaries. Before supplementing with clean soil/material samples should be taken from the pit wall and bottom. Another example is a check on reaching the

intended depth for a groundwater extraction or treatment unit and verifying the number and pattern of extraction wells);
- Log with daily information of the site: remediation activities; verification activities; visits of regulators, accidents, injuries; etcetera;
- Results of sampling and testing the quality of removed or treated contaminated material and the quality of remaining soil or sediment;
- Results of (periodical) testing of the quality of surface water or groundwater;
- All executed measurements to check health and safety aspects and compliance with environmental permits and licenses;

Communication
- Overview of institutions and persons involved (names, addresses, telephone numbers, email);
- Appointments on communication with stakeholders (authorities, companies, community, press);
- Procedure for reporting for critical and non-critical deviation of the DPR;
- Procedure for reporting incidents and accidents at the site during the remediation;
- Planning of reporting interim and final results in an evaluation report to the authority.

Monitoring programme
- For long-term remediation projects where in-situ techniques are used or where groundwater is extracted and remediated monitoring of interim results is a very important activity to verify if the remediation results are heading in the right direction;
- Part of the monitoring programme is a planned sampling and testing strategy for the quality of soil, groundwater, sediments or surface water (if appropriate);
- Criteria for the evaluation of interim results of the remediation (e.g. the concentration gradient of a parameter in groundwater);
- Action levels for evaluation or response actions.

Volume II

2.1-b Screening and response levels

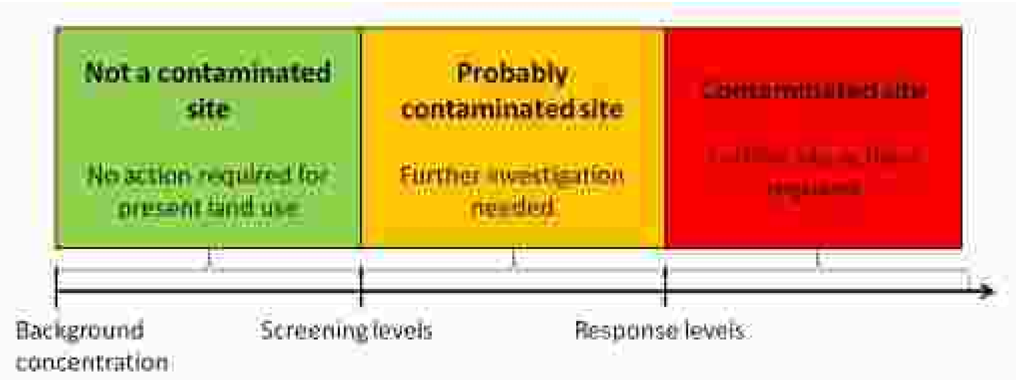
Volume II-2.1-b
Screening and Response levels

1 Introduction

This information is relevant for various Steps and Tasks in the assessment and remediation process.
Screening and Response levels are important to assess the level of contamination.

Screening levels are generic concentrations of hazardous substances in soil and sediments, groundwater and surface water at or below which potential risks to human health or the environment are not likely to occur and where no further investigation and assessment is needed. These Screening levels are distinguished for land use.

Response levels are generic concentrations of hazardous substances in soil and sediments at or above which it is very likely there is threat to human health or the environment, that may be imminent. At or above this level some form of response is required to provide an adequate level of safety to protect public health and/or the environment.



Note that that for certain contaminants such as Persistent Organic Pollutants, no background concentrations should be used, as there is no natural background for these substances.

2 Screening and Response levels

The table on next pages provides the Screening and Response levels.

Chemical Name	Chemical Groups	Hazardous waste (levels Schedule II, HW Rules, 2008) 1)	Soil (Screening and Response Levels): Response levels (Dutch Inter-vention levels) 2)	Soil: Screening levels – Soil Quality Guidelines for the Protection of Environmental and Human Health 3): Agricultural	Residential/-parkland	Commer-cial	Industrial	Groundwater for drinking water (Screening levels) 4): Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	Surface water Quality (Screening levels): The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants: Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Canadian Water Quality Guidelines for the Protection of **Aquatic Life**: Longterm in Freshwater	Canadian Water Quality Guidelines for the Protection of **Agriculture**: Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
1,1,1-Trichloroethane (TCA)	Halogenated aliphatic compounds	5000	15	0,1	5	50	50	-	-	-					-	-
1,1,2,2- Tetrachloroethene (PCE)	Halogenated aliphatic compounds	5000	8,8	0,1	0,2	0,5	0,6	-	0.03	0,04	-	-	-	-	110	-
1,1,2,2-Tetrachlorethane	Halogenated aliphatic compounds	5000		0,1	5	50	50	-			-	-	-	-	-	-
1,1,2-Trichloroethane	Halogenated aliphatic compounds	5000	10	0,1	5	50	50	-	-		-	-	-	-	-	-
1,1,2-Trichloroethene (TCE)	Halogenated aliphatic compounds	5000	2,5	0,01	0,01	0,01	0,01	-	0.005	0,02	-	-	-	-	21	-/50
1,1-Dichloroethane	Halogenated aliphatic compounds	5000	15	0,1	5	50	50	-	-		-	-	-	-	-	-
1,1-Dichloroethene	Halogenated aliphatic compounds	5000	0,3	0,1	5	50	50	-	0.014		-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	1,8	-
1,2,3,5-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	-	-
1,2,3-Trichlorobenzene	Halogenated aromatic compounds	50	11	0,05	2	10	10	-	-		-	-	-	-	8	-
1,2,4,5-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	-	-
1,2,4-Trichlorobenzene	Halogenated aromatic compounds	50	11	0,05	2	10	10	-	-		-	-	-	-	24	-
1,2-Dichlorobenzene	Halogenated aromatic compounds	50	19	0,1	1	10	10	-	-	1	-	-	-	-	0,7	-
1,2-Dichloroethane	Halogenated aliphatic compounds	5000	6,4	0,1	5	50	50	0,003	0.005	0,003	-	-	-	-	100	-/5
1,2-Dichloroethene	Halogenated aliphatic compounds	5000	1	0,1	5	50	50	-	-	0,05	-	-	-	-	-	-
1,2-Dichloropropane	Halogenated aliphatic compounds	5000	2	0,1	5	50	50	-	-	0,04	-	-	-	-	-	-
1,2-Dichloropropene (cis and trans)	Halogenated aliphatic compounds	5000		0,1	5	50	50	-	-		-	-	-	-	-	-
1,3,5-Trichlorobenzene	Halogenated aromatic compounds	50		0,05	2	10	10	-	-		-	-	-	-	-	-
1,3-Dichlorobenzene	Halogenated aromatic compounds	50		0,1	1	10	10	-	-		-	-	-	-	150	-
1,4-Dichlorobenzene	Halogenated aromatic compounds	50		0,1	1	10	10	-	0.005	0,3	-	-	-	-	26	-
1,4-Dioxane		-		-	-	-	-	-	-	0,05	-	-	-	-	-	-
2,3,4,6-Tetrachlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.1		-	-	-	-	-	-
2,4,6-Trichlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.005	0,2	-	-	-	-	-	-
2,4-Dichlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.9		-	-	-	-	-	-
2,4-Dichlorophenoxyacetic acid (2,4-D)	Pesticides (Phenoxy herbicide)	-		-	-	-	-	0,03	-	0,03	-	-	-	-	-	-
3-Iodo-2-propynyl butyl carbamate	Pesticides, Carbamate	-		-	-	-	-	-	-		-	-	-	-	1,9	-
Acenaphthene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	5,8	-
Acenaphthylene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	-	-
Acridine	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	4,4	-
Aldicarb	Pesticides, Carbamate	-		-	-	-	-	-	0.009	0,01	-	-	-	-	1	54,9/11
Aldrin	Pesticides, Organochlorine	50	0,32	-	-	-	-	0.00003	0.0007	0,00003	-	-	-	-	0.004	-
Aliphatics nonchlorinated (each)	Non-halogenated aliphatic compounds	-		0,3	-	-	-	-	-		-	-	-	-	-	-
Aluminium	Metal	-		-	-	-	-	0.03	-		-	-	-	-	Variable	5000/5000
Ammonia (total)	Inorganic	20000		-	-	-	-	0,5	-		5			5	Table	-
Ammonia (un-ionized)	Inorganic	-		-	-	-	-		-		-	-	-	-	19	-
Aniline	Organic	-		-	-	-	-		-		-	-	-	-	2,2	-
Anthracene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,012	-
Antimony (metallic)	Inorganic	50	22	20	20	40	40		0.006	0,02	-	-	-	-	-	-
Arsenic	Metal	50	50 (76)!	12	12	12	12	0,01	0.01	0,01	0,2	0,2	0,2	0,2	5	100/25

Chemical Name	Chemical Groups	Hazardous waste (levels Schedule II, HW Rules, 2008) 1)	Soil (Screening and Response Levels)					Groundwater for drinking water (Screening levels) 4)			Surface water Quality (Screening levels)					
			Response levels (Dutch Inter-vention levels) 2)	Screening levels Soil Quality Guidelines for the Protection of Environmental and Human Health 3)				Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Asbestos		5000	100	-	-	-	-		-		-	-	-	-		-
Atrazine	Pesticides, Triazine	-	0,71	-	-	-	-	0.002	0.005	0,002	-	-	-	-	1,8	10/5
Barium	Inorganic	20000	-	750	500	2000	2000	0.7	1.0	0,7	-	-	-	-	-	-
Benzene	Monocyclic aromatic compounds	50	1.1	0.05 ¤	0.5 ¤	5 ¤	5 ¤		0.005		0,01*	-	0,01*	0,01*	370	-
Benzo(a)anthracen	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,018	-
Benzo(a)pyrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		0.00001		-	-	-	-	0,015	-
Benzo(b)fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Benzo(k)fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Beryllium	Inorganic	50		4	4	8	8		-		-	-	-	-	-	100/100
Boron	Inorganic	-		2	-	-	-	0,5	5.0		-	-	-	-	1.5mg/L	5000/5000
Bromacil	Pesticides	-		-	-	-	-		-		-	-	-	-	5	0,2/1100
Bromoxynil	Pesticides, Benzonitrile	-		-	-	-	-		0.005		-	-	-	-	5	0,33/11
Cadmium	Metal	50	13	1,4	10	22	22	0.003	0.005		2	1	-	2	Equation	5,1/80
Calcium	Inorganic	-		-	-	-	-	75	-		-	-	-	-	-	-/1000000
Captan	Pesticides	-		-	-	-	-		-		-	-	-	-	1,3	-/13
Carbaryl	Pesticides, Carbamate	-	0,45	-	-	-	-		-		0.01	-	0.01	0.01	0,2	-/1100
Carbofuran	Pesticides, Carbamate	-	0,017	-	-	-	-		0.09		-	-	-	-	1,8	-/45
Chlordane	Pesticides, Organochlorine	50	4	-	-	-	-		-		-	-	-	-	0.006	-/7
Chloride	Inorganic	-		-	-	-	-	250	-		-	-	-	-	or 120 mg/L	Variable/-
Chlorothalonil	Pesticides	-		-	-	-	-		-		-	-	-	-	0,18	crops)/170
Chlorpyrifos	Pesticides, Organophosphorus	5000		-	-	-	-	0,03	0.09	0,03	-	-	-	-	0,002	-/24
Chromium (total)	Metal	-	-	64	64	87	87		0.05	0,05	2	2	-	2	-	-
Chromium, hexavalent (Cr(VI))	Metal	50	50 (78)!	0,4	0,4	1,4	1,4	0.05	-		0,1	2	-	1	1	8/50
Chromium, trivalent (Cr(III))	Metal	5000	180	-	-	-	-		-		-	-	-	-	8,9	4,9/50
Chrysene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Cobalt	Inorganic	5000	190	40	50	300	300		-		-	-	-	-	-	50/1000
Coliforms, fecal (Escherichia coli)	Biological	-		-	-	-	-		-		-	-	-	-	-	mL/-
Coliforms, total	Biological	-		-	-	-	-				-	-	-	-	-	mL
Colour	Physical	-		-	-	-	-	5 Hazen Units	-		-	-	-	-	Narrative	-
Conductivity	Physical	-		2 dS/m	2 dS/m	4 dS/m	4 dS/m		-		-	-	-	-	-	-
Copper	Metal	5000	190	63	63	91	91	0.05	-	2	3	3	-	3	Equation	Variable/variabl e
Cyanazine	Pesticides, Triazine	-		-	-	-	-		0.01	0,0006	-	-	-	-	2	0,5/10
Cyanide	Inorganic	50	50	0,9	0,9	8	8	0.05	0.2	0,07	0,2	2	0,2	0,2	5 (as free CN)	-/-
Cyanobacteria	Biological	-		-	-	-	-	-	0.0015		-	-	-	-	-	-/-
Debris	Physical	-		-	-	-	-	-	-		-	-	-	-	-	-/-
Deltamethrin	Pesticides	-		-	-	-	-	-	-		-	-	-	-	0,0004	-/2.5
Di(2-ethylhexyl) phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	16	-/-
Di-n-butyl phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	19	-/-

Chemical Name	Chemical Groups	**Hazardous waste** (levels Schedule II, HW Rules, 2008) 1)	**Soil (Screening and Response Levels)**					**Groundwater for drinking water (Screening levels)** 4)			**Surface water Quality (Screening levels)**					
			Response levels (Dutch Inter-vention levels) 2)	**Screening levels** Soil Quality Guidelines for the Protection of Environmental and Human Health 3)				Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Di-n-octyl phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	-	-/-
Dibenz(a,h)anthracene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	-	-/-
Dibromochloromethane	Halogenated methanes	5000		-	-	-	-	0.1	-		-	-	-	-	-	-/100
Dicamba	Pesticides, Aromatic Carboxylic Acid	-		-	-	-	-		-		-	-	-	-	10	0,006/122
DDT Total (Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	Pesticides, Organochlorine	50	1,7	0,7	0,7	12	12	0,001	-	0,001	10*)	-	10*)	10*)	0.001	-/30
DDD (Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane)	Pesticides, Organochlorine	50	34	-	-	-	-	0,001	-	0,001	-	-	-	-		-
DDE (Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene)	Pesticides, Organochlorine	50	2,3	-	-	-	-	0,001	-	0,001	-	-	-	-		-
DDT (Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	Pesticides, Organochlorine	50	1,7	-	-	-	-	0,001	-	0,001	-	-	-	-		-
Dichlorobromomethane	Halogenated methanes	5000		-	-	-	-	-	-		-	-	-	-	-	-/100
Dichloromethane (Methylene chloride)	Halogenated aliphatic compounds	5000	3,9	0,1	5	50	50	-	0.05	0,02	-	-	-	-	98,1	-/50
Dichlorophenols	Chlorinated phenols	50	22	0,05	0,5	5	5	-	0.9		-	-	-	-	0,2	
Diclofop-methyl	Pesticides	-		-	-	-	-	-	-		-	-	-	-	6,1	0,18/9
Didecyl dimethyl ammonium chloride	Pesticides	-		-	-	-	-	-	-		-	-	-	-	1,5	-
Dieldrin	Pesticides, Organochlorine	50	-	-	-	-	-	0.00003	-	0.00003	-	-	-	-		-
Diethylene glycol	Glycols	-		-	-	-	-	-	-		-	-	-	-	-	-
Diisopropanolamine	Organic	-		180	180	180	180	-	-		-	-	-	-	1600	2 000/-
Dimethoate	Pesticides, Organophosphorus	5000		-	-	-	-	-	-	0,006	-	-	-	-	6,2	-/3
Dinoseb	Pesticides	-		-	-	-	-	-	0.01		-	-	-	-	0,05	16/150
Dissolved gas supersaturation	Physical	-		-	-	-	-	-	-		-	-	-	-	Narrative	-
Dissolved oxygen	Inorganic	-		-	-	-	-		-		-	-	-	-	-	-
Endosulfan	Pesticides, Organochlorine	50	4	-	-	-	-	0.0004	-		10*)	-	10*)	10*)	0,003	-
Endrin	Pesticides, Organochlorine	50	-	-	-	-	-		-	0,0006	-	-	-	-	0.0023	-
Ethylbenzene	Monocyclic aromatic compounds	20000	110	0.1	5	50	50		-	0,3	-	-	-	-	90	-/2.4
Ethylene glycol	Glycols	-		960	960	960	960		-		-	-	-	-	192 000	-
Fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,04	-
Fluorene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	3	-
Fluorine		5000		-	-	-	-		-		-	-	-	-		-
Fluoride	Inorganic	5000		200	400	2000	2000	1.0	1.5	1,5	2	15	-	15	120	1000/variable
Glyphosate	Pesticides, Organophosphorus	5000		-	-	-	-		0.28		-	-	-	-	800	-/280
Heptachlor	Pesticides, Organochlorine	50	4	-	-	-	-		-		-	-	-	-	0.01	-/3
Hexachlorobenzene	Halogenated aromatic compounds	50	2	0,05	2	10	10		-		-	-	-	-	-	-/0.52
Hexachlorobutadiene	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	1,3	No data
Hexachlorocyclohexane (HCH)	Pesticides, Organochlorine	50	-	0,01	-	-	-		-		-	-	-	-	0,01	-/4

Chemical Name	Chemical Groups	**Hazardous waste** (levels Schedule II, HW Rules, 2008) 1)	**Soil (Screening and Response Levels)** **Response levels** (Dutch Inter-vention levels) 2)	**Screening levels** Soil Quality Guidelines for the Protection of Environmental and Human Health 3): Agricultural	Residential/-parkland	Commer-cial	Industrial	**Groundwater for drinking water (Screening levels) 4)** Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	**Surface water Quality (Screening levels)** The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants: Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Canadian Water Quality Guidelines for the Protection of **Aquatic Life**: Longterm in Freshwater	Canadian Water Quality Guidelines for the Protection of **Agriculture**: Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Hexachlorocyclohexane (alfa HCH)	Pesticides, Organochlorine	-	17	-	-	-	-		-		-	-	-	-		
Hexachlorocyclohexane (beta HCH)	Pesticides, Organochlorine	-	1,6	-	-	-	-		-		-	-	-	-		
Hexachlorocyclohexane (delta HCH)	Pesticides, Organochlorine	-		-	-	-	-		-		-	-	-	-		
Hydrazine(s)		5000							-		-	-	-	-		-
Imidacloprid		-		-	-	-	-		-		-	-	-	-	0,23	-
Indeno(1,2,3-c,d)pyrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	No data	-
Iron	Inorganic	-		-	-	-	-	0.3			3	3	-	3	300	5000/'-
Lead	Metal	5000	530	70	140	260	600	0.01	0.01		0,1	1	-	2	Equation	200/100
Lindane (gamma HCH)	Pesticides, Organochlorine	50	1,2	-	-	-	-	0.002	-		-	-	-	-		
Linuron	Pesticides	-		-	-	-	-		-		-	-	-	-	7	0,071/-
Lithium	Inorganic	-		-	-	-	-		-		-	-	-	-	-	2500/-
Malathione	Pesticide, Organophosphorus	5000		-	-	-	-	0.19	0.19		10	-	10	10		-
Manganese	Inorganic	-		-	-	-	-	0.1			2	2	-	2	-	200/-
Mercury (inorganic)	Metal	50	36	6,6	6,6	24	50	0.001	0.001		0,01	0,01	-	0,01	0,026	-
Methoprene		-		-	-	-	-		-		-	-	-	-	Organism	-
Methyl tertiary-butyl ether (MTBE)	Aliphatic ether	-		-	-	-	-		-		-	-	-	-	10 000	-
MCPA (Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid)	Pesticides	-	4	-	-	-	-		0.1		-	-	-	-	2,6	0,025/25
Methylmercury	Organic	5000		-	-	-	-		-						0,004	-
Methylparathion	Pesticide, Organophosphorus	5000		-	-	-	-	0.0003	-		10	-	10	10		-
Metolachlor	Pesticide, Organophosphorus	50		-	-	-	-		0.05						7,8	28/50
Metribuzin	Pesticides, Triazine	-		-	-	-	-		0.08		-	-	-	-	1	0,5/80
Molybdenum	Inorganic	5000	190	5	10	40	40	0.07	.-	0,07	-	-	-	-	73	Narrative/500
Monobromomethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-
Monochlorobenzene	Halogenated aromatic compounds	50	15	0,1	1	10	10		0.08		-	-	-	-	1,3	-
Monochloromethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-
Monochlorophenols	Chlorinated phenols	50	5,4	0,05	0,5	5	5		-		-	-	-	-	7	-
Naphthalene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	1,1	-
Nickel	Metal	5000	100	50	50	50	50	0.02	-	0,07	3	3	-	5	Equation	200/1000
Nitrate	Inorganic nitrogen compounds	20000		-	-	-	-	45	45	50	10	-	-	20	13 mg/L	-
Nitrate + Nitrite	Inorganic nitrogen compounds	20000		-	-	-	-		-		-	-	-	-	-	NO3+NO2-N
Nitrite	Inorganic nitrogen compounds	5000		-	-	-	-		-	3	-	-	-	-	60 NO2-N	-/10 000 NO2-N
Nonylphenol and its ethoxylates	Nonylphenol and its ethoxylates	-		5,7	5,7	14	14		-		-	-	-	-	1	-
Nutrients		-		-	-	-	-		-		-	-	-	-	Framework	-
n-hexane	Aliphatic hydrocarbon	-		0.49/6.5 #	0.49/6.5 #	6.5/21 #	6.5/21 #		-		-	-	-	-	-	-
Parathione	Pesticide, Organophosphorus	5000							-		-	-	-	-		-
Pentachlorobenzene	Halogenated aromatic compounds	50	6,7	0,05	2	10	10		-		-	-	-	-	6	-
Pentachlorophenol	Halogenated aromatic compounds	50	12	7,6	7,6	7,6	7,6		0.06	0,009	-	-	-	-	0,5	-

Chemical Name	Chemical Groups	Hazardous waste (levels Schedule II, HW Rules, 2008) [1]	Soil (Screening and Response Levels)					Groundwater for drinking water (Screening levels) [4]			Surface water Quality (Screening levels)					
			Response levels (Dutch Inter-vention levels) [2]	Screening levels Soil Quality Guidelines for the Protection of Environmental and Human Health [3]				Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Permethrin	Pesticides, Organochlorine compounds	50		-	-	-	-		-		-	-	-	-	0,004	-
Phenanthrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,4	-
Phenolic compounds (as C6H5OH)	compounds	5000	14	0,1	1	10	10	0.001	-		1	5	-	5	-	-
Phenols (mono- & dihydric)	Aromatic hydroxy compounds	5000		3,8	3,8	3,8	3,8		-		-	-	-	-	4	-/2
Phenoxy herbicides	Pesticides	-		-	-	-	-		-		-	-	-	-	4	-/100
Phosphorus (as P)	Inorganic	20000		-	-	-	-		-		5	-	-	-	Framework	-
Phthalic acid esters (each)	Phthalate esters	-		30	-	-	-		-		-	-	-	-	-	-
Picloram	Pesticides	-		-	-	-	-		-		-	-	-	-	29	-/190
PCBs (Polychlorinated biphenyls)	Polychlorinated biphenyls	50	1	0,5	1,3	33	33	0.0005	-		-	-	-	-	0.001	-
Poly cyclic Hydrocarbon (PAH)	Polycyclic aromatic hydrocarbons (PAH)	-	40					0.0001	-		-	-	-	-	-	-
Polychlorinated dibenzo-p-dioxins/dibenzo furans	Polychlorinated dioxins and furans	-	0,00018	4 ng TEQ.kg-1	4 ng TEQ.kg-1	4 ng TEQ.kg-1	4 ng TEQ.kg-1		-		-	-	-	-	-	-
Propylene glycol	Glycols	-		-	-	-	-		-		-	-	-	-	500 000	-
Pyrene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,025	-
pH	Inorganic Acidity, alkalinity and pH	-		6 to 8	6 to 8	6 to 8	6 to 8	6.5-8.5			5,5 - 9,0	5,5 - 9,0	5,5 - 9,0	5,5 - 9,0	6.5 to 9.0	-
Quinoline	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	3,4	-
Reactive Chlorine Species	Inorganic Reactive chlorine compunds	-		-	-	-	-		-		-	-	-	-	0,5	-
Salinity	Physical	-		-	-	-	-		-		-	-	-	-	-	-
Selenium	Inorganic	50		1	1	2,9	2,9	0.01	0.01	0,01	0,05	0,05	-	0,05	1	Variable/50
Silver	Inorganic	5000		20	20	40	40	0,1	-		-	-	-	-	0,1	-
Simazine	Pesticides, Triazine	-		-	-	-	-		0.01	0,002	-	-	-	-	10	0,5
Sodium adsorption ratio		-		5	5	12	12		-		-	-	-	-	-	-
Streambed substrate	solids Total particulate matter	-		-	-	-	-		-		-	-	-	-	Narrative	-
Styrene	Monocyclic aromatic compounds	20000	86	0,1	5	50	50		-	0,02	-	-	-	-	72	-
Sulfolane	Organic sulphur compound	-		0,8	0,8	0,8	0,8		-		-	-	-	-	50 000	500
Sulphate	Inorganic Inorganic sulphur compounds	-		-	-	-	-	200	-		-	-	-	-	-	No data
Sulphur (elemental)	Inorganic Inorganic sulphur compounds	50000		500	-	-	-		-		-	-	-	-	-	-
Suspended sediments	solids Total particulate matter	-		-	-	-	-		-		-	-	-	-	Narrative	-
Tebuthiuron	Pesticides	-		-	-	-	-		-		-	-	-	-	1,6	tame hays, and
Tellurium		50		-	-	-	-		-		-	-	-	-		-
Temperature	Physical Temperature	-		-	-	-	-		-		above				Narrative	-
Tetrachloromethane	Halogenated aliphatic compounds	5000	0,7	0,1	5	50	50		-		-	-	-	-	13,3	-/5
Tetrachlorophenols	Halogenated aromatic compounds	50	21	0,05	0,5	5	5		0.1		-	-	-	-	1	-
Thallium	Inorganic	50		1	1	1	1		-		-	-	-	-	0,8	-
Thiophene	Miscellaneous organic compound	-		0,1	-	-	-		-		-	-	-	-	-	-
Tin (inorganic)	Inorganic	5000		5	50	300	300		-		-	-	-	-	-	-
Tin (organic)		50		-	-	-	-		-		-	-	-	-	-	-
Toluene	Monocyclic aromatic compounds	20000	32	0.1	3	30	30		-	0,7	-	-	-	-	2	-/24
Total dissolved solids (TDS)	solids	-		-	-	-	-	500	-		100	600	200	100	-	00
Total hydrocarbons (TPH) (mineral oil)		50000	5000	-	-	-	-	0,5	-		10	20	10	20	-	-

Chemical Name	Chemical Groups	Hazardous waste (levels Schedule II, HW Rules, 2008) [1]	Soil (Screening and Response Levels): Response levels (Dutch Intervention levels) [2]	Soil: Screening levels – Soil Quality Guidelines for the Protection of Environmental and Human Health [3]: Agricultural	Residential/-parkland	Commer-cial	Industrial	Groundwater for drinking water (Screening levels) [4]: Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	Surface water Quality (Screening levels): The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants: Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Canadian Water Quality Guidelines for the Protection of **Aquatic Life**: Longterm in Freshwater	Canadian Water Quality Guidelines for the Protection of **Agriculture**: Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Toxaphene	Pesticides, Organochlorine	50		-	-	-	-		-		-	-	-	-	0.008	-/5
Triallate	Pesticides, Carbamate	-		-	-	-	-		-		-	-	-	-	0,24	-/230
Tribromomethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-/100
Tributyltin	Organotin compounds	50		-	-	-	-		-		-	-	-	-	0,008	-/250
Trichlorfon		-		-	-	-	-		-		-	-	-	-	0,009	-
Trichloromethane (chloroform)	Halogenated aliphatic compounds	5000	0,7	0,1	5	50	50	0,2	-	0,3	-	-	-	-	1,8	-/100
Trichlorophenols	Halogenated aromatic compounds	50	22	0,05	0,5	5	5		0.005		-	-	-	-	18	-
Tricyclohexyltin	Organotin compounds	-		-	-	-	-		-		-	-	-	-	-	-/250
Trifluralin	Pesticides, Dinitroaniline	-		-	-	-	-		-	0,02	-	-	-	-	0,2	-/45
Triphenyltin	Organotin compounds	50		-	-	-	-		-		-	-	-	-	0,022	-/820
Turbidity	solids Total particulate matter	-		-	-	-	-	1 NTU	0.1-1.0 NTU		-	-	-	-	Narrative	-
Tungsten compounds		5000		-	-	-	-		-		-	-	-	-	-	-
Uranium	Inorganic	-		23	23	33	300		0.0s	0,015	-	-	-	-	15	10/200
Vinylchloride	Halogenated aliphatic compounds	5000	0,1	-	-	-	-		0.002	0,0003	-	-	-	-	-	-
Vanadium	Inorganic	5000		130	130	130	130		-		0,2	0,2	-	0,2	-	100/100
Xylene	Monocyclic aromatic compounds	20000	17	0.1	5	50	50		-	0,5	-	-	-	-	-	-
Zinc	Metal	20000	720	200	200	360	360	5	-		5	15	-	15	30	-/50000

NR: No relaxation

¤: CCME (Canadian Council of Ministers of the Environment). 1991. Interim Canadian environmental quality criteria for contaminated sites. CCME, Winnipeg.

#: coarse/fine sediment.

!: xx (yy): xx is value from HWR 2008; yy is Dutch Intervention values. In this case levels from HWR are used because these are lowest.

*: IS: 10500:2012

[1] referring to schedule II of the Hazardus Waste rules, 2008. These levels are not relevant for the assessment of contaminated sites, but may apply if during remediation material is excavated, transported and disposed of or treated.
Note: the total content of the various substances in categories 50, 5000, 20000 and 50000 are indicated, should not exceed the specified levels to be determinated as hazardous waste.

[2] referring to Dutch intervention values (of the Circulaire bodemsanering - Circular Soil Remediation) which represent a level above which unacceptable risks may occur. The risk model by which these levels were determined takes into account a residential situation where people live and partly eat crops from the site. In this way these levels provide a relatively low level of risk, i.e. a conservative approach. The levels in this list are fixed number, no dependency on soil characteristics has to be applied.

[3] referring to CCME Canadian Environmental Quality Guidelines, these levels represent a level of negligible risk and provide a level that is regarded to enable a healthy functioning system for different types of land use.

[4] Groundwater for drinking water Screening levels: If Indian Standard for Drinking Water is not available for that parameter first referring to Guidelines for Canadian Drinkwater Quality and secondly to WHO Guidelines for drinking water.

Volume II

2.1-c Checklist preliminary site assessment report

Volume II-2.1-c
Checklist preliminary site assessment report

1 Introduction

This information is most relevant for review of the result of Task 2.1, the preliminary site assessment report. Below table provides the elements of such a report. These elements relate to the list of contents of the Site Inspection Form – Template of the *Site Inspection Protocol, Volume III-2.1-i.*

2 Checklist preliminary site assessment report

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the preliminary site assessment	
Date of recording	
Recording official	

No.	Topic	Obligatory	Status	Comments
1	Existing and general information (to be filled in before Site Inspection)	Yes		
2	Overall assessment of data and data gaps (assessed before Site Inspection)	Yes		
3	On site Reconnaissance	Yes		
4	Off site Reconnaissance	Yes		
5	Miscellaneous	Yes		
6	SITE map	Yes		
7	Sampling	Yes		
8	Overall assessment of pathways, exposure, impacts and contamination	Yes		
9	Draft Conceptual site model (CSM)	Yes		
10	Photographic Record	Yes		
11	Analysis results from sampling (table with results from sampling)	Yes		
12	Data sheet with extract of existing data from Geoenviron database – prior to Site Inspection	Yes		

Explanatory Notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II

2.2-a Checklist preliminary site investigation report

Volume II-2.2-a
Checklist preliminary site investigation report

1 Introduction

This information is most relevant for review of the output of Task 2.2, a preliminary site investigation report. The checklist below provides the elements that may be included in such a report. The specific situation determines which elements are required in a given report.

The topics in the checklist may be used as elements in Terms of Reference for the investigation of a specific site.

2 Checklist preliminary site investigation report

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the preliminary site investigation	
Date of recording	
Recording official	

No.	Topic	Data Provider / Source	Obligatory	Status	Comments
Name of investigating agency and report date					
Site identification					
	State name	Provided by client	Yes		
	Site owner	Provided by client			
	Site name	Provided by client	Yes		
	Address	Provided by client	Yes		
	GPS coordinates /and elevation: latitude and longitude in centre of the site entered as decimal	Provided by client or established based on address	Preferably		
	Current land use	Provided by client	Preferably		
Introduction					
	Purpose and scope of the investigation	Provided by client	Yes		
	Explanation of the structure of the report	Investigating agency	Preferably		
Site description					
	Explanation of information sources	Investigating agency	Yes		
	History of site use (ownership, operators, users, raw materials, waste related activities, permits, etc)	Investigation agency (Client, informed parties, discussion with local people, district administration and government databases)	Yes		

	Environs of the site (land use, groundwater use, use of water bodies, estimated number of residents or onsite workers, estimated distances to sensitive use, etc.)	Investigating agency (partly provided by government agencies)			
	Climate data (precipitation, temperature and derived information/estimated parameters such as evapo-transpiration and groundwater recharge rate estimated from this data				
	Geology and hydrogeology (stratigraphy, aquifers, depth and permeability of subsurface layers, possible karst features, etc.)	Provided by source or search of website of Central Groundwater Board, Ministry of Water Resources: http://cgwb.gov.in/	Yes		
	Hydrology and surface water (distance from site to water bodies, migration paths of rainfall to surface water, drainage, flooding patterns)				
	Results from previous investigations or incidental data	Client	If relevant		
	Result of site inspection	Investigating agency	If applicable		
	Hypothesis on type and characteristics of the contamination	Investigating agency	Yes		
	Features / targets for investigation	Client and investigating agency	If relevant		
Investigation Strategy					
	Draft Conceptual Site Model	Investigating agency	Yes		
	Screening and sampling strategy	Investigating agency	Yes		
	Fieldwork screening methods (rapid assessment tools)	Investigating agency	If applicable		
	Exploratory hole / sample location pattern (grid or targeted) and numbers of samples (soil, sediment and groundwater) , including benchmark / background samples	Investigating agency	Yes		
	Parameters for laboratory testing and chemical analysis methods / detection limits	Investigating agency	Yes		
	Applied method for quality control (QA/QC)	Investigating agency	Yes		
Fieldwork results and interpretation					
	Site conditions during fieldwork (e.g. dates, weather conditions, access to locations, etc.)	Investigating agency	Yes		
	Visual / olfactory evidence of contamination	Investigating agency, fieldwork personnel	Preferably		
	Results of screening techniques (if applied)	Investigating agency, fieldwork personnel	If applied		
	Description of ground conditions and subsurface structure (borehole / exploratory hole log description)	Investigating agency, fieldwork personnel	Yes		

	Selection of samples to be tested	Investigating agency, engineer	Yes		
	Laboratory test results	Laboratory reports	Yes		
	Comparison of laboratory test results to standards (Screening levels and Response levels)	Investigating agency	Yes		
Conclusions and recommendations					
	Does the site meet the definition of 'Contaminated Site'? (yes/no/uncertain)	Investigating agency	Yes		
	Relevant sources, pathways and receptors (soil exposure and air pathways, groundwater pathways, surface water pathways). Updated Conceptual Site Model.	Investigating agency	Yes		
	Recommendation for: • further investigation (yes/no); • notification as contaminated site (yes/no) leading to prioritisation and remediation investigation; • temporary safety measures if in the present situation significant risks to human health or environment are expected.	Investigating agency	Yes		
Annexes					
	Topographical map of area with location of the site	Client of investigating agency	Yes		
	Detailed site survey plan with location of sampling points	Investigating agency	Yes		
	Methods of fieldwork and laboratory testing	Investigating agency	Preferably		
	Borehole / exploratory excavation logs with explanation codes	Investigating agency, fieldwork personnel	Yes		
	Relevant screening and response levels	Competent authority	Yes		
	Laboratory results (including original reports) of sample analyses (soil and groundwater separately)	Laboratory	Yes		
	QA/QC results	Investigating agency			
	Photographic record	Investigating agency	Preferably		

Explanatory Notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II

2.2-b Checklist review and approval preliminary site investigation report

Volume II-2.2-b
Checklist review and approval preliminary site investigation report

1 Introduction

This information is most relevant for Step 2, Preliminary Investigation. The report of the preliminary site investigation is to be reviewed by the competent authority to prepare the decision by the appropriate official.
The checklist below provides the points of attention for the review.

2 Checklist review and approval preliminary site investigation report

The checklist below can be used to review the preliminary site investigation. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the preliminary site investigation	
Date of recording	
Recording official	

No.	Topic		Obligatory	Status	Comments
1	Checklist preliminary site investigation report	Evaluation if the report contains the elements necessary for a preliminary site investigation (refer Volume II-2.2-b)	Yes		
2	Skills and accreditations	Evaluation if the specialized agency or consultant charged with the preliminary site investigation meets the required skills and accreditations (refer Volume II-2.1-a)	Yes		
3	Stakeholder rights and interests	Evaluation if stakeholders have been involved during the course of the investigation.	Yes		
4	Points of interest to assess the results of the investigation	• All sources, pathways and receptors are identified; • Samples have been taken to assess the level of contamination of the sources and the transport via pathways • The activities to analyse the results of the investigation and comparison with the Screening and Response levels are clearly described; • Uncertainties that can have effect on the investigation result are indicated explicitly;	Yes		

		• Is cross checking of third party values required, e.g. samples and laboratory testing?			
5	Conclusion	Can preliminary site investigation report be approved? If not, which further information is required?	Yes		

Explanatory Notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II

3-a Checklist restrictions to site use and temporary safety measures

Volume II-3-a
Checklist restrictions to site use and temporary safety measures

1 Introduction

This information is most relevant for Step 3 Notification of polluted sites.

Results of (preliminary) investigation of a site may indicate actual or potential threats for human health or for the environment. In such a situation it may be necessary to organize a quick response to these threats, especially in case remediation measures are not expected to be implemented in the near future. In such a situation, restrictions to the current site use or emergency hazardous waste removal can be imposed and, to ensure proper implementation, temporary safety measures can be taken.

The checklist below provides examples for these site use restrictions and temporary safety measures regarding the protection of human health. Where surface water is involved, these measures can be applied when the water quality is negatively impacted by a contaminated site (e.g. by diffusion from contaminated sediments), or when in the current situation effluents from industrial processes and sewerage are still being discharged and are reaching, directly or indirectly, the surface water.

Measures regarding ecology (plants and animals) are part of the later steps in the process of remediation of a site. The same applies to measures regarding the prevention of threats for situations of future land use.

2 Identification of site use restrictions and temporary safety measures

The checklist below can be used to identify potential site use restrictions. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)				
Main results of the preliminary site investigation				
Date of recording				
Recording official				
Annexes#)				
Current land use	**Potential restrictions to site use when concentration levels in soil or sediment in contact zone*) exceed Response levels**	**Conclusion on whether restrictions should be applied (Yes/No) and remarks**	**Potential restrictions to site use when concentration levels in groundwater or surface water exceed Screening levels**	**Conclusion on whether restrictions should be applied (Yes/No) and remarks**
Habitation settlement/residential or school or playground or garden/park	Prohibit use of the site for current purpose. Prevent new building activities.		Prevent contact with or consumption of groundwater or surface water.	
Industrial or other commercial land	Prevent contact of labor with contaminated material. Prevent new building activities.		Prohibit extraction of groundwater or use of surface water, unless being used not for sensitive purposes (e.g. cooling water in an industrial process).	
Agricultural land	Testing of concentration levels in grass or crops and if these exceed product quality levels, prohibit the consumption of crops and prohibit livestock.		Prohibit use of drinking water for livestock and use of groundwater for irrigation.	
Forests and other natural area	Discourage or prohibit access to site.		Prohibit extraction of groundwater or use of surface water.	
Waste land	Discourage or prohibit access to site.		Prohibit extraction of groundwater or use of surface water.	
Open water body	Prevent contact with contaminated sediment.		Prevent contact with or consumption of surface water.	
Mixed and Other land use	To be derived from above suggestions.		To be derived from above suggestions.	

*) contact zone means the top level of soil and sediment (between 0.0 and 1.0 meters below the surface)

#) Annexes may include a more detailed description of site use restrictions to be imposed or temporary safety measures to ensure implementation of these, and, if applicable, a map clearly showing the area or areas on which imposed measures apply

3 Examples of temporary safety measures

Potential temporary safety measures to prevent unacceptable risks from contact with contaminated soil or sediment:

- Restrict public access to a site by placing fencing and/or by security;
- Discourage access to a site by posting warning signs;
- Assessing the need to temporarily relocate population;
- Physical emergency removal of (most) hazardous substances;
- Stabilizing waste sources such as leaking drums;
- Applying shallow top coat of clean material on locations where obvious contaminated material is present;
- Applying cover on unpaved surfaces.

In case of imminent health hazards these measures should be implemented immediately.

Potential temporary safety measures to prevent unacceptable risks from contact with contaminated groundwater and surface water:

- Temporary treatment of extracted groundwater / surface water;
- Closing groundwater extraction wells;
- Monitoring groundwater quality and spreading of contaminated plume (refer to *Volume I-11* for guidance on monitoring measures);
- Providing alternative supply of fresh water for consumption or for agricultural purposes;
- Discouraging or prohibiting use of water for bathing or swimming.

In case at a contaminated site contamination of soil, sediment, groundwater or surface water still takes place from spills measures should be taken to prevent this new contamination referring to the regulations of Section 7 of Environment (Protection) Act 1986 and to Section 3 and Schedule I of Environment (Protection) Rules, 1986.
In India there are a number of methods and measures available and used to contain or arrest a spill from a broken/damaged circular pipeline and fittings:

- There are devices which include an adaptor sleeve clamp with a provision to reasonably secure and block the liquid leakage from the pipeline. The leakage arresting device is provided in a form of ready for installation to block leakages even in locations / units requiring high standard of safety. These devices can be indigenously prepared at sites and applied or are readily available in the market.
- There are other measures adopted to contain the online leak by application of different metal putties such as Express Titanium Putty and Sticks, Steel Putty, Bronze Putty, Aluminium Putty, Underwater Putty etc. depending upon the method of characteristics (MOC) of leaking pipeline.
- Urethane impregnated, water activated special pipe tap kits designed to permanently stop live leakage up-to 4” diameter and 60 PSI are also available and used.
- Pipe Sealer is used to seal and lock threaded pipes and fittings leakages.
- Single component room temperature vulcanizing silicone sealant that forms rubber like material is widely used in leak sealing.

Volume II

4-a Checklist information for application prioritization system

Volume II-4-a
Checklist information for application prioritization system

1 Introduction

This information is most relevant for Step 4 Priority list addition. The text below presents additional guidance for the parameters needed to apply the prioritisation system. This should serve the performing party in acquiring the correct parameters.

For detailed guidance on the prioritisation algorithm we refer to the Report of Prioritization of sites (part of NPRPS-Inventory and mapping of contaminated sites, COWI, December 2015).

2 Additional guidance

Table: list of parameters and initial parameter values (source: Report of Prioritization of sites, COWI December 2015)

Parameter	S-P-R	Description	Basis	Range	Data Source
C	Source	Source concentration	Marks as Low, Med, High or Ratio to Screening Level	0 – 10	To be obtained from Site Inspection and/or from previous investigation performed at the site
Q		Quantity of source	Volume, or Low, Med, High	0 – 5	To be obtained from desktop study and/or Site Inspection
T		Toxicity Factor	A list of Chemicals	0 – 5	Obtained from the GeoEnviron Database (International classification)
M		Mobility Factor	List – chemical characteristics	0 – 5	Obtained from the GeoEnviron Database (International classification)
F	Pathway	Pathway Factor	Conn x Att	0.8-1	To be calculated based on Conn and Att
		Conn (Containment)	Site Report	0.4-0.5	Technical judgement based on site access
		Att (Attenuation)	Pathway, tables	0.4-0.5	Reflecting directness of path to receptor (including distance to receptor and groundwater vulnerability)
L	Receptors	Land use at the site	Scoring Low, Med, High Risk	0 – 10	Same classification used in Stage I prioritization
P		Population at risk	Estimated within 1 km. Log(pop) or Low, Med, High	0 – 10	Same classification used in Stage I prioritization

S		Sensitivity of receptor	Professional judgement; Scoring Low, Med, High	0 – 30	Based on observation from Site Inspection e.g. part of the population is particularly at risk or disadvantaged. Based on observed exposure to contaminants, observed impacts and generally emergency response considerations (observed conditions that may warrant immediate or emergency action (e.g. heavily contaminated groundwater/surface water used for drinking water or direct contact to heavily contaminated soil))
G		Groundwater system at risk	Use/importance of aquifer; Low, Med, High	0 – 10	Same classification used in Stage I prioritization.
SW		Surface water at risk	Use/importance of surface water; Low, Med, High	0 – 10	
E		Sensitive ecosystems	Distance to designated reserves, etc.; Low, Med, High	0 – 5	Scoring based on distance and type of sensitive ecosystems

Source

The source term is a measure of the scale and risk of the critical contaminant. This is in common with most of the systems reviewed, the approach here uses one "dominant" contaminant, but it is possible to use a combination where there are high values for several different contaminants.

The basic source term is the concentration (C) of the pollutant at the site in relation to the relevant screening value. This number can be a score reflecting the extent of the over-standard compared to the screening value. With limited sampling this parameter can be based on a professional judgement. Where there is a very wide range of high values across sites, the logarithm of the values can be used. The current uses of the site are taken into account by selecting the screening value appropriate for that land use. In cases where there is no information on the concentration (or where the sampling data is very limited or unreliable), it is possible to use estimates of the typical levels of contamination using data from similar sites or informed judgments.

To characterize the source better, terms are added for the quantity (Q), the toxicity (T) and the mobility of the contaminant (M).

The quantity is scored in terms of an estimate of size (small, medium, large). This factor can also be used to reflect a source that is a cluster of industries, where the value of Q is increased to capture the overall scale of the collective source. This is equivalent to the CEPI factor for the scale of industrial activity.

Toxicity scores are based on specific characteristics of the contaminant, as recorded in the scientific literature. The scores have been defined according to the toxicity as classified by the Department of Environment in England (DOE), and are available in the GeoEnviron database.

Mobility scores are based on specific characteristics of the contaminant, as recorded in the scientific literature. The scores have been defined according to the toxicity as classified by the Department of Environment in England (DOE), and are available in the GeoEnviron database.

Pathway

The pathway term is a measure of how direct the path from the source to the receptor is. In this model, it is structured to be a modifier of the source term.

For sites where the critical receptor is actually on the site (for example people living on polluted land), then the pathway is direct and the pathway factor (F) is unity. A land use risk factor (L) is incorporated to reflect a generalized concept of the pathway and receptor, in cases where there is little information on these. Where the receptors are off-site, then some reduction in the risk will occur, based on two main factors. First, the existence or provision of containment (or restriction of access) will reduce exposure to the source. Second, distance from the source will normally reduce the exposure (simple geometry shows that the concentration will drop with increasing radius from the site) unless there is a narrow and direct pathway (such as prevailing winds, a defined groundwater plume or a waterway).

The factor F is therefore a function of (i) containment, and (ii) attenuation. Containment is estimated in terms of the “Access to the site from local communities”. Attenuation depends on the pathway and requires judgment to assess, but there is some guidance from international practice, which suggests the appropriate ranges. The approach used is based on the parameters: distance to private wells; distance to public wells; distance to the nearest habitation and the “Aquifer protection” (Groundwater vulnerability) which refers to the degree of protection provided to the aquifer by the overlying geology. For example, an aquifer overlain by a thick clay layer will be much less vulnerable to contamination than one overlain by sand and gravel. The key factors that define the vulnerability of groundwater are: presence and nature of overlying soil; presence and nature of drift; nature of the geological strata; depth of the unsaturated zone.

Receptor

The fundamental receptor is the population potentially exposed (P), and in the present formulation, additional receptor parameters can be used for groundwater (G), surface water (W) and for sensitive environments (E). These parameters are added to the human receptor score. This means that a site which has many impacts will get a high score, while a site that has serious ecological impacts, but limited human ones (for example) will be given a score to reflect this risk. Plausible values for these parameters are being tested empirically.

The fundamental receptor is the population potentially exposed (P). This is calculated based on approach described in the Site Inspection Report. The relevant population has to be identified in order to characterize P. This will be estimated based on distance (population within 1 km of radius). The population at risk a can be determined from readily available maps (whether hard copy or GIS).

The current “Land use” at the site (L) is also included as a parameter although it is our experience from Task 1 (data collection), that information about land use can be difficult to obtain in a desktop study. The classification of land use has been defined by MoEF: Agricultural land, Waste land, Water bodies, forests, Habitation settlement, Commercial, Industrial, Mixed, Other, Not known.

Groundwater (G) and surface water (SW) at risk are included in the receptor parameters. These parameters are added to the human receptor score. Generic information can be obtained from the Central Ground Water Board and State Governments for Rivers. More specific information can be obtained during site visit/investigation.
Where the data required is not available, implementation of the method can be based on assumptions. In such cases, we propose to assume a worst case scenario for each situation. Further information should then be collected in order to verify assumptions made and further refine the priority listing. Hazard scores in relation to ground and surface water receptors is taken into account based on the industry profile. Furthermore, the use/importance of the groundwater and surface water is also incorporated in the score.

Scoring for sensitive ecosystems are based on distance and type of ecosystems. If an ecosystem is not near the site, a low value will be given for the specific site.

The model includes a sensitivity factor (S) which would signify that the exposed population (or environment) were particularly at risk or disadvantaged.

Volume II

5.1-a Checklist Detailed site investigation report

Volume II-5.1-a
Checklist detailed site investigation report

1 Introduction

This information is most relevant for Task 5.1 Detailed site investigation in Step 5, Remediation investigation.
A detailed site investigation provides clear information on the extent of the nature, extent and concentrations of the substances at the contaminated site and on the site conditions.
The checklist below provides the points of attention for the detailed site investigation report. In a way it can be regarded as a table of content for the report. For specific sites some of the elements can be found not applicable.

The topics in this checklist may be used as elements in Terms of Reference for the investigation of a specific site.

2 Checklist detailed site investigation report

The checklist below can be used to identify and assess the content of the detailed site investigation. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the detailed site investigation	
Date of recording	
Recording official	

Content of detailed site investigation report	Status	Comments
Introduction and background information • Description of the site (e.g. name, address, site plan and size); • Reason for the detailed site investigation; • Summary of the previous investigations at the site; • Information of the parties involved in the remediation investigation process and allocation of their roles; • Scope of the investigation; • Explanation of the structure of the report.		
Site situation • The lay-out on the site (present land use, infrastructure, buildings, use of the surrounding area, included natural features such as lakes, rivers, streams found at least partially within the boundaries of the property) and in the area beyond the site covering the pathway;		

• Description of history of the land use and possible causes of the contamination (included constructed features such as, underground storage tanks, lagoons, ditches, sumps within buildings, and waste storage areas); • Typology of the contaminated site; • Geology, geohydrology and soil structure and ground conditions of the site in case of contaminated soil and groundwater (depth of groundwater, thickness of aquifers, seasonal groundwater fluctuations; the lithology and vertical permeability of the unsaturated zone; the stratigraphy, structure, geometry, porosity, hydraulic conductivity, storage properties, transmissivity, and groundwater flow direction of the saturated zone). • If monitoring or drinking water wells have been installed: review of the monitoring results; include data why and when a well was installed and by whom and technical data (depth, filter length, monitoring data, sample and lab methods) • Soil survey information at a scale of 1:20 000 or larger; on-site map and appropriate cross-sections showing soil types, soil depth and other soil parameters that may be related to location and extent of contaminants; • Climatic conditions (precipitation, seasonal variations, estimated infiltration rates); • Morphological and hydraulic aspects including e.g. seasonal variations in water level and floods and and areas affected by floods to estimate the impact of contaminated sediments.		
Investigation strategy • The conceptual site model (CSM) with the combinations of source-pathway-receptor) of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density); • Data gaps in the CSM and points for investigation; • Screening and sampling technical equipment; • Sampling rationale and design (media, locations, pattern and depth of samples), including background samples; • Number of samples; • Screening of observations wells or necessity for drilling new wells; • Methods for establishing stratigraphy and characteristics of subsurface layers; • Analytical test parameters / determinants required.		
Fieldwork and laboratory testing • Description of executed activities; • Site conditions during fieldwork (e.g. dates, weather conditions, access to locations, etc.) • Visual / olfactory evidence of contamination • Results of screening techniques (if applied) • Description of ground conditions and subsurface structure (borehole / exploratory hole log description) or water body; • Selection of samples to be tested; • Laboratory test results; • Quality assurance and quality control; • Possible deviations from sample plan and reasons involved.		

Analysis and interpretation of exploratory data • Comparison of laboratory test results to standards (Screening levels and Response levels); • Description of situation of the contamination in the various media (soil, groundwater, sediment, surface water, air, biota) including depth and extent of contamination and including estimated quantity of polluted media; • Development of groundwater flow, surface water flow, and mass transport models. (if required) • Implications of contamination, soil structure and general physical, chemical, ecological and spatial site conditions for remediation options; • (Seasonal) contour maps of groundwater flow and explanation of estimated groundwater processes; • Possible influence of seasonal climatological situation on groundwater and surface water; • Contour maps and cross-sections to show spatial distribution of contaminants; graphical displays that present the available data in their spatial context; sample values for data on maps or cross-sections; colors; grey scales, or symbols to high-light the locations of the highest sample values; • Updated Conceptual Site Model, identifying sources, pathways and receptors.		

Conclusions and recommendation
• Conclusions on the scope and objectives of the investigation with clear indication of known data gaps and possible uncertainties;
• Recommendations for
    ◦ further investigation;
    ◦ temporary safety measures if in the present situation significant risks to human health or environment are expected. This may include monitoring of a contaminated plume in groundwater.		

Annexes • Topographical map of area with location of the site • Detailed site survey plan with location of sampling points • Methods of fieldwork and laboratory testing • Borehole / exploratory excavation logs with explanation codes • Relevant screening and response levels • Laboratory reports • Calculations or modelling results and explanation characteristics of the model used • Maps indicating contamination of soil, sediment and groundwater • Background literature and sources • Photographic record		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

5.2-a Checklist risk assessment report

Volume II-5.2-a
Checklist risk assessment report

1 Introduction

This information is most relevant for Task 5.2, Risk Assessment. The table below presents a checklist of all elements a report on risk assessment may contain. As such, it may serve the performing consultant as well as the reviewing authority. It should be noted that the selection of elements any specific report should contain depends on the specific situation. Therefore, any review should be preceded by an analysis of which elements are relevant for the situation at hand.

The report on risk assessment may be integrated into the report of the detailed site assessment.

2 Checklist risk assessment report

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the risk assessment	
Date of recording	
Recording official	

Content of Risk assessment report	Status	Comments
Introduction and background information • Description of the site (e.g. name, owner, address, site plan and size, GPS-coordinates); • Summary of the previous investigations at the site; • Information of the parties involved in the assessment and remediation process and allocation of their roles; • Reason for and objectives of risk assessment.		
Site situation • The situation of the contamination at the site (present land use, infrastructure, buildings, use of the surrounding area); • Description of history of the land use and cause of the contamination; • Description of area with respect to existing land use, demographic profile, social economic and environmental conditions of the people in receptor areas, flora and fauna; • Comparison of concentration levels against Screening and Response levels.		

Content of Risk assessment report	Status	Comments
Relevant source-pathway-receptor combinations • The conceptual site model (CSM) with the combinations of source-pathway-receptor of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density); • Relevant exposure pathways, preferably illustrated with diagram.		
Results of generic quantitative risk assessment modelling • Tool/model used to quantify risks • Site-specific information used for modelling o Representative concentrations in soil, sediment and groundwater o Size of contamination in soil (3D) o Size of contamination in groundwater (3D) o Size of the site (contaminated and not contaminated) o Level of groundwater o Soil type (%organic matter, % clay, grain size, hard rock) o Surface water in the environment o Drinking water extension in the environment o Groundwater flow direction and estimated speed o Use of the contaminated site and the vicinity o Establishment of the site (buildings, basements, roads, crops) o Receptors on-site and off-site • Model results and comparison to critical exposure value		
Results of detailed quantitative risk assessment • Reason for detailed quantitative risk assessment • Collection of additional information (methodology used for obtaining data) • Data obtained, e.g. contaminants investigated, contaminant concentration levels in the relevant contact media (e.g. air, dust), relevant specific circumstances • Results		
Conclusions and communication • Clear statement on unacceptable risks identified • Possible uncertainties and information gaps, necessity for further investigation • Recommendations for further steps, setting remediation options and development of remediation options		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

5.3-a Background information for setting remediation objectives

Volume II-5.3-a
Background information for setting Remediation objectives

1 Introduction

This information is most relevant for Task 5.3 Development of remediation options. In developing effective targets for remediation it is important to discuss the policy goal on contaminated sites. This is related to the definition of contaminated sites, the inventory of sites and the technical, financial, legal and organisational possibilities to implement the NPRPS.

Contaminated sites are defined by situations which pose existing or imminent threats to human health and/or the environment. Remediation should be aimed at reducing these threats. The threats have been determined for the present or expected future land use. An important decision needed from the competent authority is the form(s) of land use and the level of protection the remediation should take into account. A sensitive form of land use (e.g. residential area) requires more remediation effort than a less sensitive form of land use (e.g. industrial area). This with respect to human health as well as regarding the ecological value of an area.

To reduce the threats for an intended form of land use an intervention is required in the source-pathway-receptor-combination of a specific situation. This means that either the source needs to be reduced, the pathway between source and receptor needs to be cut off or the receptor needs to be protected or removed. Section 5.4 in Volume II presents options for such remediation interventions.

The key issue is to what level the threats should be reduced. In this regard, there are three options to consider:

Approach 1, Generic total threat reduction in soil, sediment or groundwater
Implementation of the approach of generic total threat reduction is aimed at reducing the identified threats to zero level, rendering the site fit for any use ('multifunctional'). Internationally, 'zero' is most commonly translated into 'as low as technically achievable'. To achieve this the source of the contamination needs to be removed or treated completely, as contaminant concentration levels need to be reduced to background levels.

Approach 2a, Generic fitness for use threat reduction in soil or sediments
Implementation of the approach of generic fitness for use threat reduction in soil or sediment is aimed at reducing threats to a generic acceptable level given the site's present and/or future use. To achieve this:

- The constituents in the source of the contamination need to be removed or treated to a generic level set for the present and/or intended future land use, or
- The pathway from contamination to receptor needs to be cut off, or
- The receptor needs to be protected or removed.

Approach 2b, Cost effective groundwater approach

Implementation of the cost effective groundwater approach is aimed at reducing threats to an acceptable level, while the remediation action is still cost effective. To achieve this contaminants are removed from the pathway to a degree where the costs of the removal is in balance with the amount of contaminants (mass) removed from the pathway. Contaminants in the source of the contamination are removed or treated to such a degree that this action benefits the actions in the pathway. Whenever the receptor is threatened it needs to be protected.

Approach 3a, Site specific fitness for use threat reduction in soil or sediments

Implementation of this approach is aimed at reducing threats to a site-specific acceptable level given the site's present and/or future use. To achieve this:

- The contamination needs to be removed to a predetermined site-specific level at which the contamination is considered to present no threat. This remediation level is based on site-specific risk assessment and is typically less strict than the generic (robust for all uses) level, or
- The pathway of the contamination to the receptor needs to be cut off exactly according to a specific use and spatial planning of the site, or
- The receptor needs to be protected or removed.

The required remediation efforts are most comprehensive in approach 1), less in approach 2a),most limited in approach 3a) and cost balanced in approach 2b). Conversely, the flexibility of the present and future land use and absence of restrictions and required efforts for monitoring and control increase from approach 3) to approach 1). Figure II-5.3-a.1 below illustrates this for soil and sediments and figure II-5.3-a.2 for groundwater.

Figure II.5.3-a.1 Remediation effort and consequences for the different approaches to remediation of soil or sediment

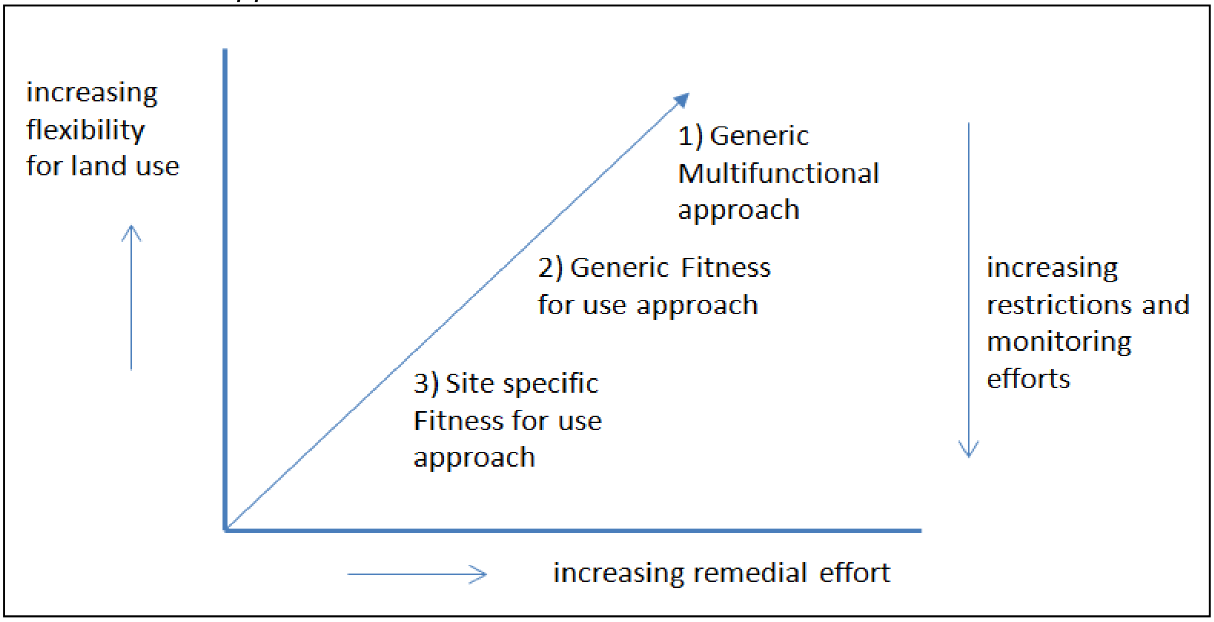
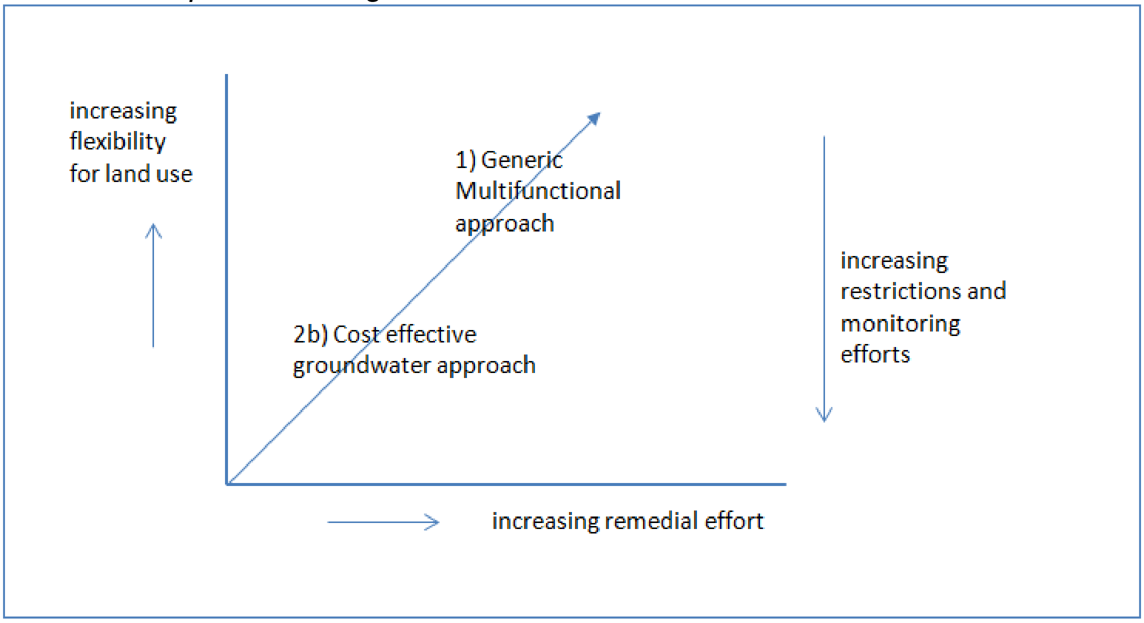


Figure II-5.3-a.2.2 Remediation effort and consequences for the different approaches to groundwater remediation



2 Standard based approach: multifunctional remediation

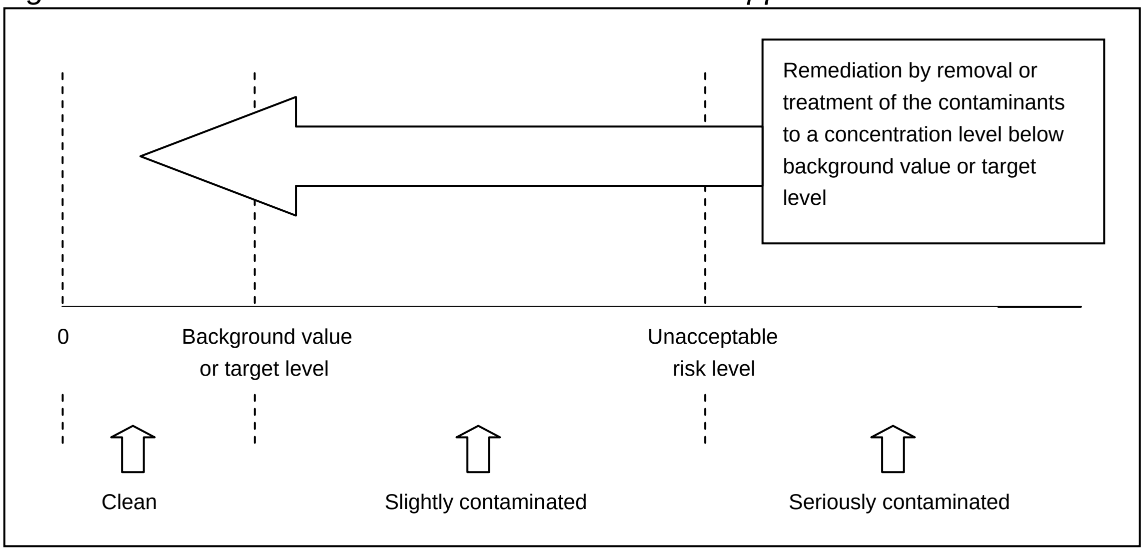
In most of the countries presently dealing with soil remediation the wheels have been set in motion by major incidents. Especially where these cases received widespread media attention governments were quick to respond. The clearest example of this is the United States where, barely a year after Love Canal became a household name, the federal Comprehensive Environmental Response and Liabilities Act (CERCLA) came into force (1980). Perhaps most remarkable was the fact that, aside from the development of regulation, the (sometimes huge) funds needed for concrete action also came swiftly. This was the case in the US, but also in the Netherlands, where, as in the US, a residential district built on top of a dangerous chemical waste dump (in Lekkerkerk) was the catalyst. The examples mentioned here had impact across national borders, as was the case with the Seveso explosion in northern Italy, which prompted other countries and the EU into action.

As the incidents were major, created clear danger to human health and to the environment in general, regulations in those early days tended to be strict. The front running countries, especially in Europe (e.g. Denmark and the Netherlands), generally adopted the principle of multifunctionality, meaning they aimed at remediating all contaminated land to pristine conditions. This would entail the restoration of soil quality from an intervention value back to a standard target level or natural background level regardless of site characteristics or site use. The objective of this approach was to reach a situation in which the remediated sites would be fit for all use after remediation. To reach this objective, all contaminated sites would need to be remediated back to pristine conditions.

This approach also meant a standard based approach, consisting of either complete removal or removal to a specific concentration, where criteria did not take into account the present or future use of the site. The obvious advantage of this approach is a simple, very clear decision-making system, easy to apply and hardly giving any space for discussion as the target levels are well defined and non negotiable.

If multifunctional soil remediation is impossible for site specific reasons containment of the contamination is a fall back option. As this containment needs to reach a situation comparable to complete removal it needs to be designed in such a way that its application results in the lowest possible emission and multiple site use options. Figure II.5.3-a.2 demonstrates the multifunctional soil remediation approach.

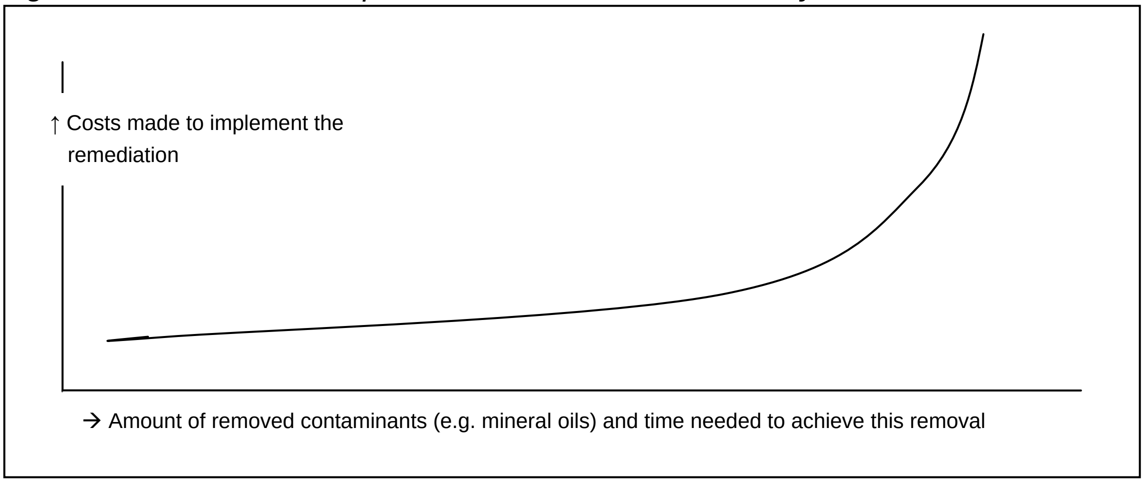
Figure II.5.3-a.2 Multifunctional soil remediation approach



The notion that “multifunctionality should be the ultimate aim of contaminated land remediation, as being the only truly sustainable option” certainly seems a defendable one. Especially if we consider the direct link that was made almost one on one in those days between soil contamination and very serious threats to human health. Actually, the Netherlands has long defended the principle of multifunctionality in practice. Even after a study in the early 1990s had shown that pursuing this strategy would amount to an estimated cost of € 45 billion (equivalent to close to € 75 billion or U$ 100 billion of today). Or, as it was translated then, even with more than € half a billion per annum (to be borne by a population of around 17 million) it would take a full century for the operation to be completed. This example illustrates what became clear elsewhere as follows: “[multifunctionality] may not be technically feasible, nor economically viable in the short term.”

An example, showing the costs and inefficiency of a multifunctional remediation approach: the removal of the final 'drop' of mineral oil from a mineral oil contaminated soil is a technical challenge disproportionate to its achievement. The same goes for the costs, as well as for the energy needed: the extraction of the last drop is likely to demand much more energy than represented by the drop itself. Figure II.5.3-a.3 demonstrates this principle, which helps to determine a site based optimum in the remediation target to be established.

Figure II.5.3-a.3 Principle of soil remediation efficiency



Note. Scales in this figure are arbitrary

During the first half of the 1990s the idea also gained ground that (re)development was actually slowed down considerably ('stagnation' was the word used) by the soil contamination on many urban, and otherwise prime, sites. This raised the question whether the policies in place influenced this stagnation in any way. Looking back, this certainly seems to be the case: the more stringent the policy leaned towards a standard based multifunctional approach, the higher the cost of remediation would be, leading to a significantly reduced interest in (potentially) contaminated sites by developers. Even in the densely populated areas of north-western Europe the economically best option often was to develop a Greenfield.

While some countries, notably Finland, the Netherlands and Switzerland, have retained, at least in theory, the ultimate goal of multifunctionality, risk based criteria tied to land use are presently in use in most countries.

With the drawbacks of the multifunctional approach apparent, that does not mean this approach has been phased out completely: it is still used in specific circumstances. For instance, in case the contaminated area is small, the costs of a multifunctional approach are relatively low. And a standard based approach may well be the most appropriate option for the liable party when his policy is to avoid any future liability issues.

3 Risk based approach: fitness for use remediation

From the previous Section we can digest that the multifunctional soil remediation approach is generally speaking not necessary from a health and environmental point of view, economically not feasible and not sustainable. The general response has been the introduction of a risk based approach. This approach focuses on the removal or treatment of contaminants as far as needed to reach a quality fit for one or more specific functional site uses, assessing all unacceptable risks prior to remediation. The result is an approach with “less stringent generic criteria tied to risk and future land use, and more flexible site-specific risk assessment and clean up procedures”.

This approach can be based on either generic target levels for different types of land use or on site specific target levels. In either case, within this fitness for use approach the remediation measures can provide a generic protection level for a form of land use or can be directed to a very specific spatial design of the intended land use. An example to illustrate this: for a residential area the remediation measures can be designed with maximum flexibility of the exact use of land within the boundaries of the site. In this way everywhere houses can be built and gardens with crops can be situated everywhere. However, remediation measures can also be designed for a very specific spatial plan for a residential area: this enables contamination levels below roads and buildings to be higher than the concentration levels in the gardens. While this way remediation efforts can be limited this approach also results in more restrictions for future use of the site, and this specific spatial site plan needs to be maintained and monitored.

In this ‘fitness for use’ approach the risks the contamination poses to human health and the environment are decreased to a level acceptable for the present land use. In case land use is expected to change in the near future, present as well as projected land use can form the basis for this approach. A basic principle that has been retained in taking the step towards a risk based approach is called the ‘stand still’: for each site reuse or redevelopment the soil and groundwater quality should at least be fixed or improved.

Figures II.5.3-a.4 and II.5.3-a.5 show the principle of the ‘fitness for use’ (risk based) approach.

Figure II.5.3-a.4 ‘Fitness for use’ approach of the source: reducing levels of contamination in soil

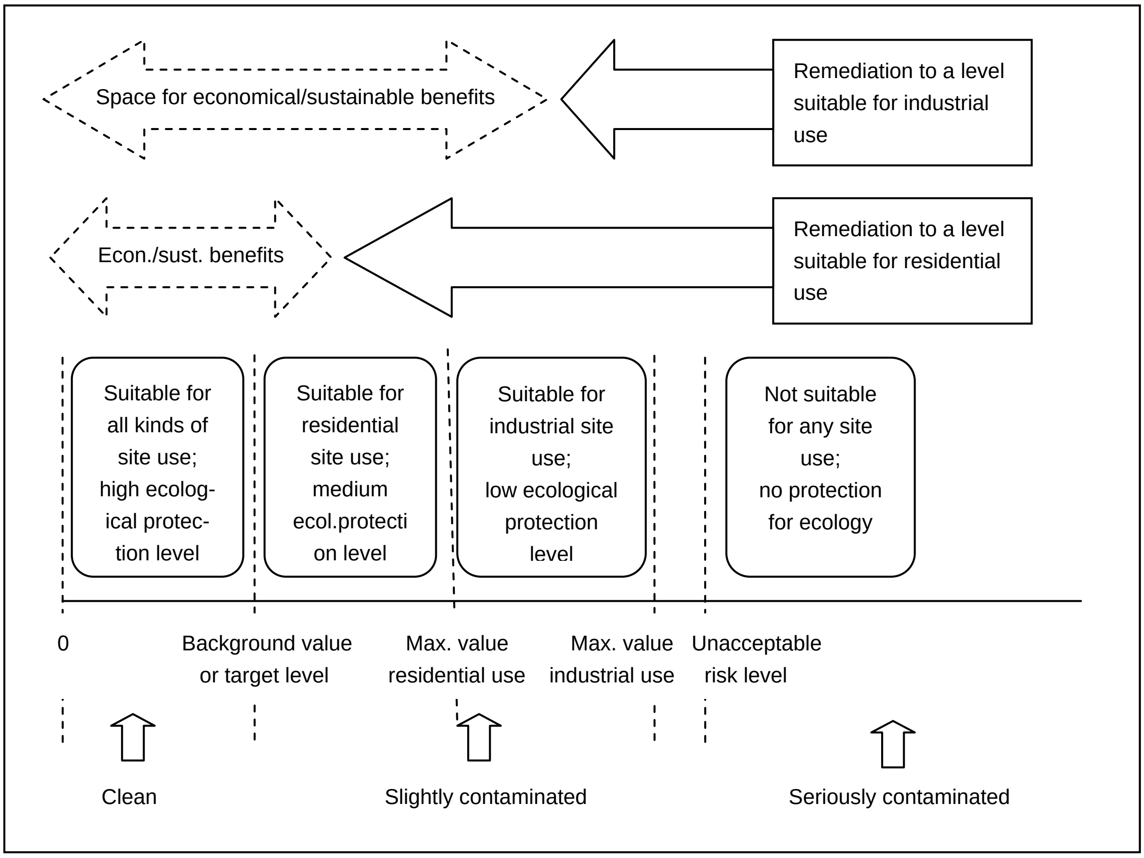
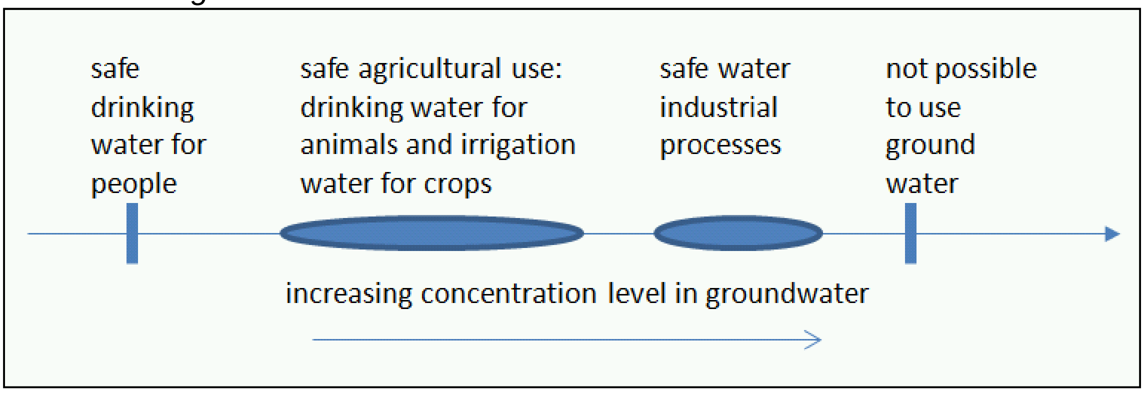


Figure II.5.3-a.5 ‘Fitness for use’ approach of the source: reducing levels of contamination in groundwater



For each source-pathway-receptor-combination this approach can be used. In cases of immobile soil contamination, such as many heavy metals, this will result in assessing the quality of the top layer only, as the quality of this part of the soil is responsible for most human and environmental risks. The assessment of mobile contaminations is presented in Section 5 Cost effective groundwater approach.

In case only the top layer has to be assessed, much effort can be saved on the assessment of the contamination below the top layer. Using this approach, a risk based site management framework can be built, providing an opportunity to balance between a scientific underpinning of the assessments and pragmatism to deal with contaminated sites, anticipating site specific or region specific preconditions. The maximum values for site use offer basic safety warranties.

A contamination without any receptors does not present any risks. In case it is decided to remediate such a contaminated site anyway, e.g. to improve the quality of an aquifer to meet drinking water standards, there may be time to consider alternative remediation options. At this point even more cost effective remediation approaches come into view.

A more recent development is to combine sustainability aspects with the 'fitness for use' approach, offering a balance between human health and environmental protection versus the opportunity to reuse contaminated soil and to optimize economic aspects of site redevelopment. This approach offers a lot of space for economical and sustainable benefits without any public health or safety sacrifices. When developing a national program for remediation of multiple contaminated sites, these benefits are crucial for the feasibility of the complete program.

4 Preliminary conclusion for applicability in India

From the Sections 2 and 3 above it can be derived that a standard based approach is, in comparison with a risk based approach, relatively simple and easy to understand, also for non professionals. This characteristic can help in drawing support, especially from residents, when proposing remediation solutions. On the other hand, a standard based approach is less flexible: once the standards have been set the system in a way determines which decisions need to be taken in individual cases. Experience shows that this can lead to remediation approaches hardly taking into account the local situation. Moreover, the standard based approaches have shown a tendency to require considerably more financial means.

By contrast, a risk based approach is aimed specifically at developing remediation options fitting the local situation. Furthermore, a risk based approach in assessing remediation options seamlessly fits on to the site assessment phase, which usually includes risk assessment to determine the need to remediate. Also, in a risk based approach, individual site specific targets for remediation sometimes can be combined with other target values, e.g. drinking water standards. A risk based approach, however, requires more data, in particular on the local situation. In most cases, the investment in acquiring these data yields larger returns later, by saving significantly on the costs of the remediation, which, after all, is aimed at the specific situation.

India is a cost sensitive market, meaning that any solution needs to use local components, hardware, engineering, skill level of operators, level of automation, etc. India is also very diverse, geographically, as well as socially, culturally and ethnically. This means the general approach should enable stakeholders to tailor remediation options to any local situation. This has implications at all levels of abstraction, from the regional cultural situation right down to the practical level, taking into account aspects such as the availability of electric power.

Based on the above, the risk based approach seems, in general, to provide the best opportunities for India. Having said that, it should be noted that the risk based approach also requires more knowledge than the standard based approach. This is an important point considering soil remediation is a nascent profession in India at the time of writing this document. Therefore, development of a sound structure for knowledge development and dissemination merits due attention.

5 Cost effective groundwater approach

This information is most relevant for Tasks 5.4 and 5.5, in cases where the remediation option to be selected involves dealing with groundwater contamination.

Contamination in groundwater can spread to huge volumes and contaminate large areas. In areas where groundwater or downstream surface water is used as a drinking water source, groundwater contamination is likely to affect this strategic and fundamental asset.

Figure II.5.3-a.3 illustrates that remediation of contaminated groundwater can be very cost intensive and can take a long time. In cases where costs are expected to be too high, it could be interesting to consider cost effective approaches. Costs and amount of contamination to be removed are balanced with the functional use of the groundwater. Such an approach is only possible if there are no actual risks to human health or the environment, or where these risks can be addressed during the remediation phase, or in case pre-consumption treatment of local produced groundwater is feasible. This is because cost effective approaches of groundwater contaminations often mean a long term remediation process such as natural attenuation (NA) or long term groundwater management.

Basic principles of cost effective groundwater approaches are:

- maximum use of natural attenuation techniques;
- long term monitoring of potential hazards;
- assessing sources of spreading. As the remediation of the source of spreading is a relatively cost intensive operation, the remediation of the source can be balanced to the level of spreading which is acceptable;
- use of fall back scenarios only in case of unacceptable spreading (actual threatened receptor).

Cost effective remediation of groundwater offers opportunities for alternative solutions by combining different groundwater uses. For example, a costly pump and treat remediation of a groundwater contamination can be combined with other parties using groundwater for industrial use or irrigation. After having treated the contaminated groundwater it can be offered for use by other parties or even for drinking water supply, thereby effectively reducing the remediation costs. If necessary, a temporary drinking water piping system can be implemented as a safety measure before and during the remediation works.

Volume II

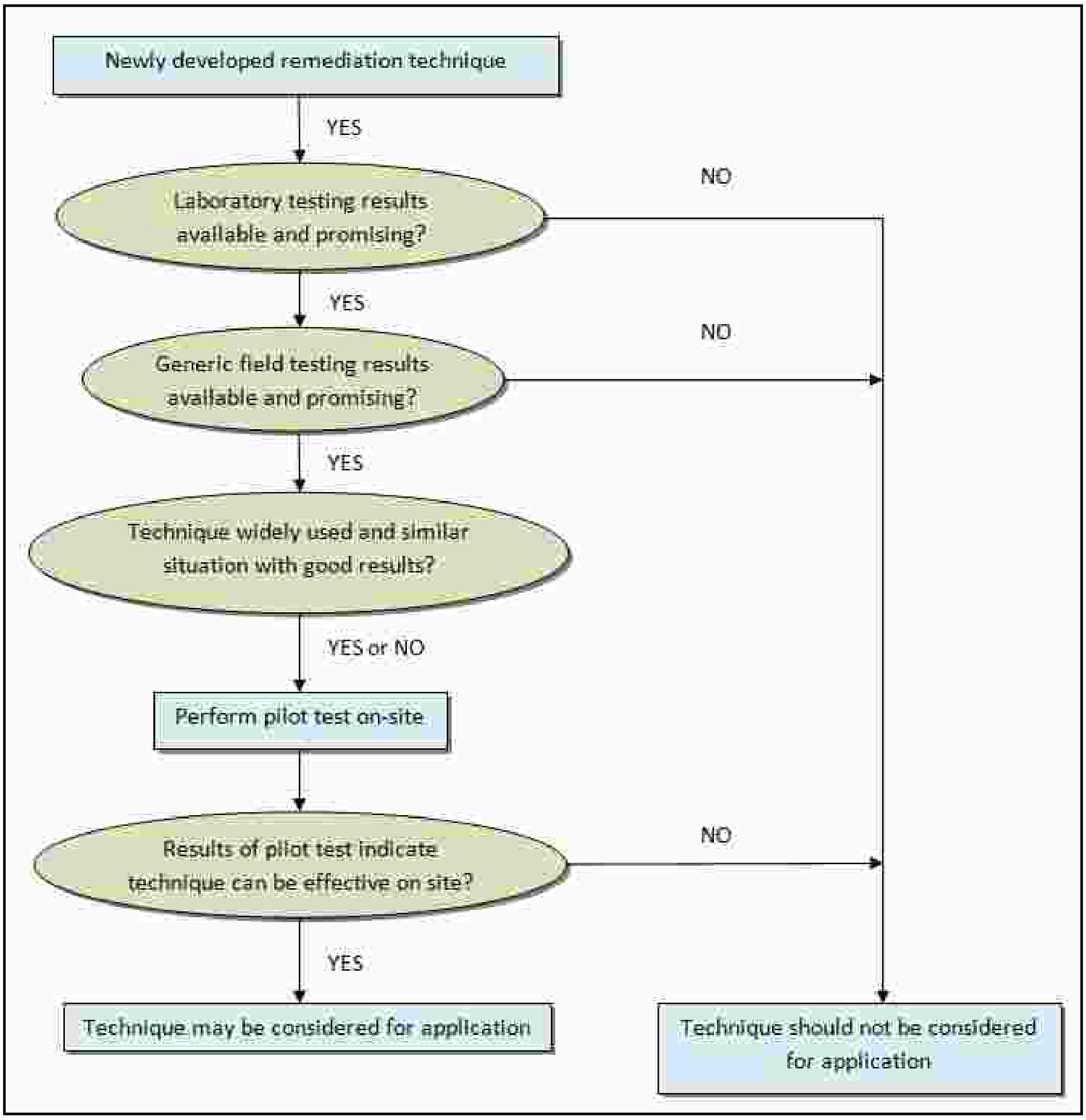
5.4-a Flowchart application newly developed remediation techniques

Volume II-5.4-a
Flowchart application newly developed remediation techniques

1 Introduction

This information is most relevant for Task 5.4, Development of remediation options. A remediation technique must be technically proven before it can be applied with any guarantee of success. This means a newly developed remediation technique needs to be tested, first under laboratory circumstances, but eventually also in the field, before it should be considered for application at a specific site.
The flowchart below presents guidance on the process of considering newly developed remediation techniques for application.

2 Flowchart application newly developed remediation techniques



Volume II

5.5-a Checklist criteria for comparison and appraisal of remediation options

Volume II-5.5-a
Checklist Criteria for comparison and appraisal of remediation options

1 Introduction

This information is most relevant for Tasks 5.4 Development of remediation options and Task 5.5 Selection remediation option.

All remediation options should meet the main aim for remediation: reducing the significant risk to an acceptable level. In case this level is not reached by a remediation option, either additional measures are necessary or the remediation option is not appropriate for the case at hand.

The applicability and expected success of remediation options can be assessed using criteria. These criteria can be divided into two groups:

Generic criteria that should be assessed, regardless of the setting of the site:

- Risk reduction potential: degree to which health and environmental risks are reduced beyond the target level of remediation, offering an extra surplus of risk reduction or protection. Applicable to both immobile and mobile contaminants.
- Technical success potential: technical complexity, implementability, robustness (intrinsic capacity of the technical measures to accommodate changes in circumstances or performance), and the availability of technical capacity. If the technical risks related to these technical aspects are low or can be mitigated, the technical success potential can be regarded as high.
- Cost and benefits. Included are:
  - Costs for activities like post remediation actions and measures needed due to failure of originally planned measures;
  - Benefits due increased value of the site and to combined implementation with site redevelopment.
- Sustainability: influence of the remediation on other environmental aspects, e.g. air quality, space, ecology, waste, energy.

Criteria of which the assessment will depend on site specific circumstances and preconditions:

- Time: time needed to implement the remediation objective. Note: the time needed to implement post remediation actions is considered as a cost and/or social aspect.
- Post remediation site use: degree to which the site can be used for present, planned or not yet known site uses regarding its technical characteristics.
- Social criteria: social acceptance and impacts:
  - Physical Impacts to neighbourhood such as noise, dust, odour, traffic;
  - Changes in the way the local communities function;
  - Changes that could affect the site usage by communities.

The selection of remediation options is a balancing act: one option can be favourable regarding one criterion but can have a negative score on other criteria.
Below, the elements for consideration in the appraisal and selection of remediation options are presented for each criterion.

Elements for consideration for the generic criteria
Criterion: risk reduction potential

- Level of risk reduction: the more the level of risk is reduced the more guarantees can be given the remediation will be adequate and more forms of land use can be practised without threats to health or environment;
- Phasing of remediation: stepwise improvement of a site's situation is preferable when final targets can be met in the future. Provided that most important actual risks are in sight and dealt with as needed. Stepwise improvement means a reduction in remediation efforts and provides more opportunity for natural breakdown of contaminants;
- Size of contamination source: total removal or treatment of the constituents at contaminated sites with a relatively small and well accessible source of contamination is preferable;
- Volume of contamination: the volume of contamination that could be left on site is often too small compared to the efforts required to remove all of it. The extra efforts include the design process of a ‘fitness for use’ approach, remediation actions that are likely to be required if the site will be redeveloped again after a period of time or post remediation actions for management of the contaminations remaining on site;
- Surrounding area: when in a larger area more than one site is contaminated it often makes sense to develop a management strategy for the approach of the whole area rather than taking extensive remediation measures only at that specific site;
- Removal of load: the more kilograms of contamination is removed from the soil, the more the remediation will have a long term impact. Condition however is that the constituents have not been transformed into more toxic or mobile components;
- Liability: in certain cases third parties choose to avoid any risk of liability. In those cases, a remediation where all contamination is removed or treated is the best bet to not end up with post remediation obligations;
- Options for alignment with other developments: if remediation of a site is combined with the redevelopment of the site the redevelopment influences the selection of the remediation option. The alignment of the remediation design to the redevelopment plan (and vice versa). In some cases, land use planning may have to be adapted to the contamination situation, e.g. considering remediation of a former toxic waste dump for agricultural or housing purposes would require high costs, whereas the use as an industrial area may be very cost-effective.

Criterion: technical success potential
This criterion involves technical complexity, implementability, robustness (intrinsic capacity of the technical measures to accommodate changes in circumstances or performance), and the availability of technical capacity.

- Robustness: the remediation measures should remain effective, also under changing conditions or in case of poor maintenance. The measures should be ‘simple if possible, and complex only when necessary’;
- Stage of development of remediation technique: in case a remediation technique has only proven itself on a laboratory scale, no guarantees for reaching the remediation objective can be given. Proven remediation techniques should be preferred, innovative techniques may be considered after a well documented field trial shows potential success. Pilot tests may help to establish whether the technique is applicable under the specific situations at hand. This means a newly developed remediation technique needs to be tested, first in laboratory circumstances, but eventually also in the field, before it should be considered for application at any given site;
- Risk of failure: when risk of failure of the remediation strategy is considerable, additional costs to implement a fall back scenario should be taken into account.

Criterion: costs and benefits
- Costs for post remediation actions and extra measures needed due to failure;
- Benefits due to increased value of the site and to alignment of implementation with site redevelopment;
- Total budget of the redevelopment and, within that, means available for remediation measures.

Criterion: sustainability
- Influence of the remediation on other environmental aspects, e.g. air quality, space, ecology, waste, energy.

Elements for consideration for the site specific criteria
Criterion: time
This criterion is about the time needed to reach the remediation objective. Note: the time needed to implement post remediation actions is considered as a cost and/or a social aspect.
- Time aspects: the longer a remediation takes the higher the risk of ‘loss of control’. Especially in case long term post remediation measures should be taken, this is an important element.

Criterion: post remediation site use
This criterion is about the degree to which the site can be used for present, planned or not yet known site uses regarding its technical characteristics. Examples of this are 1) A complex and high-tech system (walls, interception system, ...) will be out of balance when changes on the site are made. A flexible system can easily accommodate those changes during its lifespan, 2) The more of the contaminants is removed during the remediation phase, the less risks will emerge in case of site use changes, and 3) Changes in site conditions can remobilize contaminants immobilized during the remediation phase.
- Disinvestments in case of site use changes: the more costs are spent on physical measures, the more costs are lost in case these measures need to be removed during future redevelopment. This can be avoided by later site use restrictions, but these will be difficult to maintain. A better solution is offered if this is considered as a design starting point;

- Time available for remediation: in case of a redevelopment plan a short and high cost remediation approach can be selected just to prepare the site within certain planning limits for the actual redevelopment. In cases where little time is left for remediation, a standard based high cost remediation approach taking only little time, might be selected.

Social criteria: social acceptance and impacts

- Physical Impacts to neighbourhood such as noise, dust, odour, traffic;
- Changes in the way the local communities function;
- Changes that could affect the site usage by communities;
- The degree to which a function fitted remediation may be aligned with redevelopment objectives.

Volume II

5.5-b Checklist Remediation investigation report

Volume II-5.5-b
Checklist Remediation investigation report

1 Introduction

This information is most relevant for Task 5.5 Selection remediation option. The investigation leading to the selection of the most applicable remediation option is reported in a Remediation investigation report. This checklist presents the aspects that should be addressed in such a report. This general checklist should be adjusted for a specific situation.

2 Checklist Remediation investigation report

The checklist below can be used to identify and assess the content of the detailed site investigation. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the Remediation investigation	
Date of recording	
Recording official	

No.		Topic	Obligatory	Status	Comments
1	**CSM and risk assessment**				
	A	Historical information of the site including subsequent site and groundwater use, industrial processes leading to soil contamination	Yes		
	B	Geology	Yes		
	C	Geohydrologie	Yes		
	D	Description of all contaminations (sources) including spreading processes (pathways)	Yes		
	E	Description of risks (receptors)	Yes		
2	**Remediation objectives**				
	A	Risks to be remediated	Yes		
	B	Objectives of the remediation	Yes		
	C	Requirements of the remediation including other activities which are executed simultaneously (redevelopment)	Yes		
	D	Stakeholders	Yes		
	E	Funds	Yes		
	F	Other legislation to be met	Yes		
	G	Preconditions to be met with the remediation	Yes		
3	**Description remediation options**				
	A	Technical aspects to achieve the remediation objective an requirements	Yes		
	B	Effects on surrounding and counter measures: sound, noise, soil vibration, groundwater drop, traffic hinder (intensity and duration), stability of soil	Yes		
	C	Practical aspects of implementation: preparation of / on the site, safety measures	Yes		
	D	Measurements / sampling program to verify the progress and final result of the implementation phase	Yes		

	E	Communication with stakeholders prior to, during and after the remediation	Yes		
	F	Production and/or usage of: energy, soil, air, water and activities or technical measures to dispose of products	Yes		
	G	Risks and mitigating measures during implementation: technical, planning, concentration levels	Yes		
	H	Legal aspects: permits and legal constraints	Yes		
	I	Planning: preparation phase, implementation, extensive phase of in situ techniques, post remediation measures	Yes		
	J	Post remediation measures: description of residual contaminations and subsequent technical and management measures necessary to prevent future human and ecological risks and risks of spreading of the contaminations	Yes		
	K	Costs: implementation, post remediation phase and risks	Yes		
	L	Point for further investigation during DPR or pilot phase	Yes		
4	**Evaluation of possible remediation options**				
	A	Points for evaluations	Yes		
	B	Method for evaluations	Yes		
	C	Evaluations of options (qualitative or quantitative)	Yes		
	D	Selection of most favourable remediation option	Yes		
	E	Point for further investigation during DPR or pilot phase			
5	**Annexes**				
		Maps, x-sections, tables technical schemes	Yes		

Explanotary notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

5.5-c Checklist review and approval Remediation investigation report

Volume II-5.5-c
Checklist Review and approval Remediation investigation report

1 Introduction

This information is most relevant for Step 5, Remediation investigation. The report of the Remediation investigation is to be reviewed by the competent authority to prepare the decision by the appropriate official.
The checklist below provides the points of attention for the review.

2 Checklist review and approval Remediation investigation report

The checklist below can be used to review the preliminary site investigation. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the Remediation investi-gation	
Date of recording	
Recording official	

No.	**Topic**		**Obligatory**	**Status**	**Comments**
1	Checklist Remediation investigation report	Evaluation if the report meets all elements for a Remediation Investigation Report VII-5.5-b.	Yes		
2	Skills and accreditations	Evaluation if the specialized agency or consultant charged with Remediation investigation report meets the required skills and accreditations.	Yes		
3	Stakeholder rights and interests	Evaluation if the stakeholder rights are guaranteed. A thorough stakeholder involvement offers a good basis for securing stakeholder warranties.	Yes		
4	Third party values	Validation by third parties of key elements to evalu-ate potential risks of individual options [1].	Yes		
5	Points of interest to assess the results of the Report	• Is any remediation option with potential better result missing? • Are the remediation objectives of all described options likely to be reached when implementing these options? • Are all options well described to make a final selection? • Does the evaluation / ranking of all options meet all objectives and requirements set (including those from other legislation)?	Yes		
6	Conclusion	Can Remediation investigation report be approved? If not, which further information is required?	Yes		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic
[1] e.g. risk assessment calculations, samplings, results of pilot testing

Volume II

6-a Checklist DPR including verification plan

Volume II-6-a
Checklist DPR including verification plan

1 Introduction

This information is most relevant for Step 6, Remediation design, DPR.
The design of the remediation is meant to detail out the selected remediation option into separate activities. These technical and organisational aspects of these activities and their environmental impact should be described in Detailed Project Report or remediation design plan (DPR).

The checklist below provides the points of attention when designing the remediation activities. In a way it can be regarded as a table of content for DPR. The elements of a verification plan are included in this table. For specific sites some of the elements can be found not applicable.

2 Checklist DPR including verification plan

The checklist below can be used to identify and assess the different elements of the DPR. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the DPR	
Date of recording	
Recording official	

Content of DPR	**Status**	**Comments**
Introduction and background information • Description of the site (e.g. name, owner, address, GPS-coordinates, site plan and size); • Reason for the remediation; • Summary of the previous investigations at the site; • Information of the parties involved in the remediation process and allocation of their roles.		
Site situation • The situation of the contamination at the site (present land use, infrastructure, buildings, use of the surrounding area); • Description of history of the land use and cause of the contamination; • Typology of the contaminated site; • Geology, geohydrology and soil structure and ground conditions of the site in case of contaminated soil and groundwater.		

• Morphological and hydraulic aspects in case of contaminated sediments in surface water and seasonal variations in water level; • The conceptual site model with the combinations of source-pathway-receptor) of concern. A detailed description of the present contamination with characteristics (parameters, concentration, extent in horizontal and vertical direction, mobility, density);		
Remediation approach • Objective of the remediation related to regulatory requirements and the selected remediation option; • Combination of the remediation with reconstruction activities at the site, possible impact on planning and results of the remediation measures and description of measures to manage this impact; • Targets levels of the remediation to be achieved; • Remediation techniques to be used: technical description; • Stages in the remediation process (if appropriate); • Necessity of a pilot testing of the remediation technique.		

Detailed description of the remediation process
• Preparation activities:
    ° removal of buildings, infrastructure, foundations, tanks in order to achieve access to the contaminated material; if removal is not possible, which working constraints will have to be dealt with;
    ° mobilisation of equipment to the site;
    ° necessary staff during the remediation;
    ° organising the working and storage areas at the site;
    ° possible access limitations to parts of the site or the neighbouring area;
    ° availability of suitably licensed treatment or disposal capacity off site;
• Overview of the necessary permits and licenses;
• Measures necessary to prevent damage or nuisance (such as dust, odours, noise and dirt on roads) on the site and in the surrounding area (including possible transport of removed waste to a treatment or disposal site);
• Measures to improve sustainability aspects (e.g. reducing energy);
• When excavation of soil or dredging of sediment is part of the remediation strategy:
    ° size and contours of the excavation (area and depth);
    ° estimated volume of material to be excavated (in-situ and after excavation) and destination of the material (on-site rearranging or off-site treatment or disposal, for which the procedures of HWR-2008 may apply);
    ° necessary abstraction of groundwater;
    ° in case of dredging sediment: necessary preparation on the water way, lake, river or canal;
    ° temporary storage of material in depots;
    ° quality of the clean material to be used to replace the removed contaminated material;		

• When groundwater abstraction is part of the remediation strategy:
  ◦ Pattern and depth of wells;
  ◦ Volume and planning of the abstraction period;
  ◦ Results model calculations of the groundwater remediation;
  ◦ Method of discharging abstracted water and necessary treatment;
• When in-situ techniques are part of the remediation strategy:
  ◦ Equipment to be installed (indication, pattern and specific location);
  ◦ Maintenance activities during the active phase of the remediation;
• Checkpoints during the remediation process and action levels or other criteria for assessment the intermediate results;
• Possible effects of the remediation measures and mitigating activities to be carried out to minimize these effects;
• Possible uncertainties in the situation (e.g. the delineation of the contamination is not very detailed at one side of the location) and ways of dealing with these risks.
• Planning of the remediation activities (project implementation schedule);
• Programme for supervision and environmental verification;
• Suggestions for sampling, testing and other measurements related to verification (to be elaborated further in a verification plan):
  ◦ what are be the key parameters to verify the success of the progressing remediation;
  ◦ which monitoring equipment should be installed before and during the remediation.
• Expected restrictions to future land use after finalizing the remediation activities;
• Identification of the need for post remediation activities;
• Health and safety aspects during the remediation:
  ◦ possible exposure to contaminated material by skin contact, ingestion or inhalation;
  ◦ necessary measures to prevent these risks (description of these measures to be elaborated in step 8);
  ◦ safety measures regarding equipment and transport.
• Record keeping, use of a log;
• Estimation of costs, with distinction between costs for installing equipment, short term measures and costs for long term remediation and maintenance. Sometime an analysis of risks and variation of the costs;
• Insurance;
• Communication aspects in the process of implementation of the remediation. These communication aspects are related to restrictions and nuisance during the remediation and the possible restriction for land use in the final situation. Relevant stakeholders for the communication should be indicated;
• Maps, drawings, calculations must be added as annexed to the remediation design report.		

Content of verification plan This Section presents a generic checklist for a verification plan, being part of the Detailed Project Report. In this verification plan the activities are described for verifying the results of the remediation.		
Supervision and environmental verification • Description of the tasks of the supervision and environmental verification of remediation works; • Possible response actions to deal with uncertainties; • Critical points in the remediation process where the progress should be assessed, a list of critical points during the remediation is given below (examples are the moment where an excavation; has reached its ultimate boundaries. Before supplementing with clean soil/material samples should be taken from the pit wall and bottom. Another example is a check on reaching the intended depth for a groundwater extraction or treatment unit and verifying the number and pattern of extraction wells); • Log with daily information of the site: remediation activities; verification activities; visits of regulators, accidents, injuries; etcetera; • Results of sampling and testing the quality of removed or treated contaminated material and the quality of remaining soil or sediment; • Results of (periodical) testing of the quality of surface water or groundwater; • All executed measurements to check health and safety aspects and compliance with environmental permits and licenses;		
Communication • Overview of institutions and persons involved (names, addresses, telephone numbers, email); • Appointments on communication with stakeholders (authorities, companies, community, press); • Procedure for reporting for critical and non critical deviation of the DPR; • Procedure for reporting incidents and accidents at the site during the remediation; • Planning of reporting interim and final results in an evaluation report to the authority.		
Monitoring programme • For long-term remediation projects where in-situ techniques are used or where groundwater is extracted and remediated monitoring of interim results is a very important activity to verify if the remediation results are heading in the right direction; • Part of the monitoring programme is a planned sampling and testing strategy for the quality of soil, groundwater, sediments or surface water (if appropriate); • Criteria for the evaluation of interim results of the remediation (e.g. the concentration gradient of a parameter in groundwater); • Action levels for evaluation or response actions.		

Explanotary notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II
6-b Example format cost estimation remediation

Volume II-6-b
Example format cost estimation remediation

1 Introduction

This information is most relevant for Step 6, Remediation design, DPR.
All remediation activities descried in the DPR are summarized and a costing is made for each of these activities. These activities do not only involve the technical measures of the remediation. The preparation of the work, including costs for demolishing building or replacement of inhabitants may be involved as well. The costs for management, supervision and verification of the remediation works should be included as well. The previous costs of investigation of the site and preparation of the remediation design may be summarized to the total of relevant costs.

2 Example format cost estimation remediation

An overview of cost elements of a remediation is presented in this Example format. The costing should include volumes, amounts and unit prices.

Some of the cost elements may be estimated quite accurately, some elements may be difficult to estimate. It may be useful to apply a bandwidth for elements which have large impact on the total costs.

1983663/2022/HWM Br

Estimation of remediation costs

example: soil excavation, off site treatment of soil, groundwater abstraction and treatment

no	discription activities	unit [1]	cost / unit	quantity	amount (INR excl taxes)
A	**Preparation remediation [2]**				
	surveying of site lay out	item			
	establishing boundaries of remediation site and install temporary fences with signs	item			
	construction of temporary access road to the site	item			
	installing and renting temporary office space for contractor and project manager	week			
	removal of surface covering (asphalt etc.)	m2			
	removal of surface covering (vegetation)	m2			
	removal of buidlings or other objects on the site	item			
	mains: installation of water & electricty to the site	item			
	sub-total preparation of remediation				
B	**Excavation of contaminted soil [3]**				
	Excavation of non contaminted soil and transport to depot on site	m3			
	Excavation of contaminted soil	m3			
	transport of contaminated soil for off-site treatment or landfilling [4]	MT			
	delivery and transport to the site of non contaminated soil	m3			
	reuse of non contaminated soil from the site	m3			
	filling of excavation pits with non contaminated soil including compacting	m3			
	repaving of surface	m2			
	replanting of the site	m2			
	sub-total excavation of contaminated soil				
C	**Groundwater remediation: installation of abstraction wells and treatment plant for contaminated water [5]**				
	borings for installation groundwater abstraction wells. Depth 20 m-bg including well screens	item			
	undergound mains: piping for water including underground installation, electricity for wells	m1			
	installation of pumps to be installed in wells (deepwells)	item			
	well covering for abstraction wells	item			
	preparation of site for location treatment plant	item			
	on site installation of treatment plant. Capacity 10-20 m3/h	item			
	connecting wells etc. to equipment	item			
	start up process treatment plant	item			
	sub total installation of wells and treatment plant				
D	**General costs [6]**				
	on-site guidance & project management during excavation and installation of groundwater remediation	weeks			
	permitting	item			
	preparation of contract and tendering of the works	item			
	insurances	item			
	general costs, contracting costs	item			
	subtotal general costs				
E	**Off-site treatment contaminated soil [7]**				
	off-site treatment or lanfdilling of contaminated soil	MT			
	sub-total treatment contaminated soil				
	total investment (A, B, C, D, E)				
	<u>**Operational costs groundwater remediation**</u>				
F	**Operation groundwater remediation [8]**				
	operation of water treatment plant incl. minor adjustments	month			
	maintenance treatment plant and abstraction wells etc	month			
	electricity consumption kwh/year	month			
	groundwater sampling on the site and surrounding area for verification remediation process	item			
	groundwater analyses verification remediation process	piece			
	project management groundwater remediation	month			
	report on remediation progress	piece			
	final report evaluation on the remediation	item			
	subtotal groundwater remediation				
	total operational costs (F)				
	Total costs excluding taxes				-

[1] type of unit is depending on the activity
[2] this section should specify all contracting actions before actual remediation starts. Remediation plans etc. are not included.
[3] this section should specify all actions related to the excavation of contaminated soil
[4] site for the soil treatment should be known before remediation start
[5] this section should specify all actions related to the installation of the groundwater remediation system
[6] this section includes mainly project management issues carried out by a consultant
[7] the method for soil treatment should be known before remediation start
[8] this section includes the operational costs for the groundwater remediation

1983663/2022/HWM Br

Estimation of remediation costs

example: soil vapor extraction and in-situ air sparging

no	discription activities	unit [1]	cost / unit	quantity	amount (INR excl taxes)
A	**Preparation remediation [2]**				
	surveying of site lay out	item			
	establishing boundaries of remediation site and install temporary fences with signs	item			
	construction of temporary access road to the site	item			
	installing and renting temporary office space for contractor and project manager	week			
	mains: installation of water & electricty to the site	item			
	sub-total preparation of remediation				
B	**Pilot plant soil vapor extractie & air sparging [3]**				
	design of pilot plant	item			
	installation soil vapor extraction wells incliding drilling and well material	piece			
	installation air sparging well incliding drilling and well material	piece			
	installation of SVE and air sparging equipment	item			
	piping for the wells and connection to SVE-blower and Air sparging compressor	item			
	base line measurement soil and groundwater before start pilot	item			
	start pliot and initial measurements	item			
	monitoring during pilot (various measurements and sampling)	week			
	analyses (soil air, water) during pilot	piece			
	operational costs SVE and air sparging during pilot	week			
	report pilot including assessment of application and design details for full scale remediation	item			
	sub-total pilot				
C	**Installation of soil vapor extraction & air sparging system**				
	borings for installation of SVE and air sparging wells	item			
	installation of SVE wells, depth 5 m -bgs	piece			
	installation of air sparging wells , depth 10 m -bgs	piece			
	undergound mains: piping for SVE and air sparging underground installation	m1			
	installation of SVE and air sparging equipment for full scale remediation	item			
	installation for off gas air treatment: activated carbon	item			
	connecting varius well etc. to equipment for SVE and air sparging	item			
	sub total installation of SVE and air sparging and off gas treatment plant				
D	**General costs [4]**				
	on-site guidance & project management during installation of in-situ systems	weeks			
	permitting	item			
	preparation of contract and tendering of the works	item			
	insurances	item			
	general costs, contracting costs	item			
	subtotal general costs				
E	**Off-site treatment contaminated soil [5]**				
	off-site treatment or landfilling of contaminated soil	MT			
	sub-total treatment contaminated soil				
	total investment (A, B, C, D, E)				
	Operational costs in-situ remediation				
F	**Operation SVE & air sparging**				
	operation of soil vapor extraction system	month			
	maintenance and replacing activated carbon off gas treatment plant	month			
	electricity consumption kwh/year	month			
	removal of installations including off gas treatment plant	item			
	sub-total operation in-situ system				
G	**Project management in-situ remediation [6]**				
	soil gas sampling on the site verification remediation process	item			
	ground & groundwater analyses verification remediation process	piece			
	project management in-situ remediation	month			
	analyses (soil air, water)	piece			
	report on remediation progress	piece			
	final report evaluation on the remediation	item			
	subtotal project management				
	total operational costs (F+G)				
	Total costs excluding taxes				-

[1] type of unit is depending on the activity
[2] this section should specify all contracting actions before actual remediation starts.
[3] a pilot plant is not always required
[4] this section includes mainly project management issues carried out by a consultant
[5] this only applies for the core drillings of the wells
[6] in-situ remediations require various measurements to control all the systems and operation

Volume II

7-a Checklist review and approval Detailed Project Report

Volume II-7-a
Checklist review and approval Detailed Project Report

1 Introduction

This information is most relevant for Step 6, Remediation design, DPR. The Detailed Project Report of the specific site is to be reviewed by the competent authority to prepare the decision by the appropriate official.
The checklist below provides the points of attention for the review.

2 Checklist review and approval Detailed Project Report

The checklist below can be used to review the DPR. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the DPR	
Date of recording	
Recording official	

No.	Topic		Obligatory	Status	Comments
1	Checklist Detailed Project Report including verification plan	Evaluation if the report meets the elements necessary for a DPR (see VII-6-a)	Yes		
2	Skills and accreditations	Evaluation if the specialized agency or consultant charged with the DPR meets the required skills and accreditations	Yes		
3	Stakeholder rights and interests	Evaluation if the stakeholder rights are guaranteed. A thorough stakeholder involvement offers a good basis for securing stakeholder warranties. Have the results of the environmental and social impact assessment been shared with relevant stakeholders?	Yes		
4	Points of interest to assess the results of the remediation	• The remediation objectives according to the selected remediation option (in task 5.5) should be met; • The remediation should be technically well feasible; • The results of the environmental and social impact assessment are acceptable and within regulatory permits. Additional measures will be applied where negative impact of the remediation measures may occur;	Yes		

		• There are clear criteria to assess the progress and final result of the remediation; • The activities to verify the progress and results of the remediation are clearly described; • Uncertainties which may have effect on the remediation result are indicated explicitly and the DPR provides scenarios and measures in case these uncertainties will occur.			
5	Conclusion	Can Detailed Project Report be approved? If not, which further information is required?	Yes		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

8.1-a Checklist permits for remediation works

Volume II-8.1-a
Checklist permits for remediation works

1 Introduction

This information is most relevant for Step 8, Implementation of remediation.
This Section presents a checklist of the regulatory permits, licenses and/or consents that should be applied for during the preparation and authorization (Task 8.1).

This is a generic checklist, to be adjusted to the situation of a specific remediation project. Depending on the local or regional regulations the necessary permits and licenses will vary. Aspects relating to land ownership and land use are not included in this checklist.

2 Checklist permits for remediation works

The checklist below may be used to identify and assess the required permits. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the DPR: description of remediation design	
Date of recording	
Recording official	

Permit, license, consent	**Status**	**Comments**
Environmental Clearance (to be confirmed from competent Authority) (Clearance from MoEF) • Environmental Clearance will include Environmental Impact Assessment, Public Hearing etc. as stipulated in EIA notification SO.1533 dated 14.09.2006		
Preparation of the site (permission from Urban development) • Demolition or removal of buildings or infrastructure; • Cutting trees; • Constructions in canals, rivers or lakes anticipating dredging of sediment.		
Waste management licenses (permission from Pollution Control Board) • License to excavate or extract polluted material at the site and to store it temporarily; • Way of treatment of this material at the site (mobile plant for on-site treatment);		

• Transportation of waste material (distance, final destination, means of transport, route of transport with impact of dust and noise on inhabitants along the route).		
Groundwater abstraction and purification permits (Permission from Ground Water Board) • Groundwater abstracted from the soil per day; • Groundwater abstraction from wells (volume, radius of influence);		
Treatment and discharge of water (Permission from Pollution Control Board) • Installation and operation for treatment/purification of extracted groundwater; • Discharge of treated water into surface water or sewage system.		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

References:

- EIA so1533.pdf
- The Water (Prevention and Control of Pollution) Rules 1975.pdf
- THE AIR (PREVENTION AND CONTROL OF POLLUTION) RULES, 1982.pdf
- The Environment (Protection) Rules, 1986.pdf
- HWRulesFinalNoti240908.pdf
- MSW Rules 2000.pdf
- The Bio-Medical Waste (Management and Handling) Rules, 1998.pdf
- The Noise Pollution (Regulation and Control) Rules, 2000.pdf
- The Plastic Waste (Management & Handling) Rules, 2011.pdf
- THE PUBLIC LIABILITY INSURANCE RULES, 1991.pdf
- Central Motor Vehicles Rules 1989.htm
- MODEL RULES FA 1948.htm
- The Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules, 1996.pdf
- National Green Tribunal Act 2010.pdf

Volume II

8.2-a Checklist prequalification for remediation

Volume II-8.2-a
Checklist prequalification for remediation

1 Introduction

This information is most relevant for Step 8, Implementation investigation. The remediation works may be appointed to a third party, typically a contractor. This checklist is also useful for Step 11, Post remediation activities.

The client who contracts out this assignment may be a private person, private organization or the local, State or Central authority. This checklist provides support for the client in the selection of a contractor. To ensure a good quality remediation, it is vital that this third party can demonstrate the expertise, skills and compliance relevant for the assignment. Where available, it is preferable if this is supported by relevant accreditations.

At the outset, it is very important that the client/organization responsible for remediation provides clear Terms of Reference (ToR), which should at least include the objectives of the remediation, the required output and the possible constraints. These should be described in the bid document, developed in Task 8.2 Contracting. Without a clear bid document the third party may interpret the situation differently resulting in the proposed activities not leading to the required output. Furthermore, if more than one party is requested to tender an offer, an unclear bid document can lead to differences that render a fair comparison impossible. If the client is a private organization it may be advisable to contact the competent authority for assistance.

2 Checklist for the prequalification for remediation

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main aim of the appointment	
Date of recording	
Recording official	

Prequalification criteria for selection of the specialized organization	**Status**	**Comments**
Information about Firm: Firm's Background; Firm's Registration; Firm's Class Certificate; Bank Solvency; Banking History; Tax History; Liability History;		

Black Listing History; Joint ventures / tie ups; Type of firm – Pvt. Ltd..- Proprietary – Partnership; Work experience: Bid capacity.		
Financial capability: Financial statement & Profit & Loss of last 5 years; Return on net worth ratio; Quick ratio; Current ratio; Asset turnover ratio; Ratio of Fixed assets / long term Liabilities; Debt ratio; Insurance of equipment; Working capital.		
Technical capability: Firm's building work experience; Equipment and Plant ownership by the contractor; Onsite laboratory equipments; Experienced project managers / civil engineers / electrical engineers; Labours (skilled & unskilled); Training programme for the personnel; Personnel experience in similar projects; Job expertise.		
Management capability: Business evaluation; Change in core Management; Head office organization structure; Coordination & safe administration; Number of technical staff; Number of non-technical staff; Failure to complete past project; Current work load; Research & Development.		
Construction capability: Cost control; Schedule / time Control; Quality Management System; Quality assurance; Resource Management; Number of Sub-contractors & Work load on sub-contractor; Method of procurement.		

Past experience: Scale of projects completed; Type of projects completed; Experience in local area; Similar type of 5 projects completed; Time overruns in past projects; Cost overruns in past projects; Quality achieved in past project. Experience in social aspects regarding investigation of sites for environmental reasons.		
Reputation condition: Arbitration History; Trade History; Past relationship with Client / consultant; Awards; Past projects claims History; Termination of contract; Relationship with sub-contractor.		
Health and safety policy: Safety management system Accidents in past projects Insurance of personnel		
Use of Information Technology & Services: Project Management Software Personnel knowledge in IT / Software Level of Technology		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

8.3-a Checklist Health and Safety plan

Volume II-8.3-a
Checklist Health and Safety plan

1 Introduction

This information is most relevant for Task 8.3 Execution, supervision and verification remediation works, and for Step 11 Post remediation action.

2 Checklist Health and Safety plan

The checklist below provides the elements that should be included in any Health and Safely plan for a soil remediation project. For specific sites some of the elements can be found not applicable. The checklist may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Contractor	
Supervisor	

Content of Health and Safety plan	Status	Comments
All onsite workers should be provided with the following materials • Jackboots, resistant to chemicals and with a safety sole (steel plate); • Liquid tight overall; • Liquid tight gloves; • Safety helmet. Additional materials in case the presence of toxic fumes or dust (e.g. asbestos) is expected: • breath and eye protection; • measurement instruments.		
Measures in preparation of remediation • Prepare Health and Safety plan; • Start log; • Mark “contaminated zone” and mark “clean zones”; • Ensure availability of first aid materials and relevant first aid knowledge; • Inform onsite workers on relevant Health and Safety aspects, through oral and written information and education.		
Hygiene during remediation measures • Limit the number of people needed in the contaminated area; • Work with machines as much as possible; • Have onsite workers work on the windward side of the contamination whenever possible; • Prohibit observation by means of smelling; • In case of handling barrels full protective measures (including breathing protection) apply (see above);		

Content of Health and Safety plan	Status	Comments
• Forbid eating, drinking and smoking in the contaminated area; • Ensure that, whenever people leave the contaminated area, boots are cleaned and coveralls are left in the contaminated area; • Prevent the generation of dust (e.g. by spraying water); • Ensure availability of face and breath protection throughout; • Forbid open fire. Machinery: • Ensure any excavating equipment is provided with overpressure cabin and dust filter.		
Optional measurements during remediation measures • PID (Photo Ionization Detector); • Toximeter (gas testing vials); • Cyanide measurements; • H_2S-measurements; • Active coals vials; • Personal air sampling by badges (attachment of badges near inhalation zone); • Explosion meters (oxygen-explosion meter).		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

8.3-b Checklist supervision and verification remediation measures

Volume II-8.3-b
Checklist supervision and verification remediation measures

1 Introduction

This information is most relevant for Task 8.3, Execution, supervision and verification remediation measures. The performance of supervision and verification of remediation measures is usually commissioned to an independent third party environmental supervisor

2 Checklist supervision and verification remediation measures

The checklist below provides the elements that should be monitored during supervision and verification of remediation measures. For specific sites some of the elements can be found not applicable. The checklist may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Summary of remediation works	
Date of recording	
Contractor	
Recording supervisor	

Supervision and verification of remediation measures	**Status**	**Comments**
Supervision and verification (technical) *Elements for supervision and verification plan* • Outline supervisor tasks; • Potential response actions to deviations from remediation plan; • Critical activities in the remediation process. A list of these is presented in the table below this one. *Elements for ongoing supervision and verification* • Log on daily progress of remediation, supervision and verification measures, like visits by regulators; • Results of sampling and testing the quality of removed or treated contaminated material and the quality of remaining soil or sediment; • Results of (periodical) testing of the quality of surface water or groundwater; • Results of all measurements performed to check health and safety aspects and compliance with environmental permits and licenses;		
Communication *Elements for supervision and verification plan* • Contact information of institutions and persons involved (names, addresses, telephone numbers, email addresses); • Agreed actions concerning communication with stakeholders (authorities, companies, community, press);		

Supervision and verification of remediation measures	Status	Comments
• Procedure for reporting critical and non critical deviation from the DPR; • Procedure for reporting incidents and accidents at the site during the remediation; • Planning of reporting interim and final results in an evaluation report to the authority; • Verification of results of remediation has to be carried out by a party independent from contractor, owner, occupier and other stakeholders. *Elements for ongoing supervision and verification* • Record events concerning communication and their results in the daily log.		
Monitoring (only in long-term remediation projects) *Elements for supervision and verification plan* • Sampling and testing strategy for monitoring the quality of soil, groundwater, sediments or surface water (whatever is appropriate); • Criteria for the evaluation of interim results of the remediation (e.g. the concentration gradient of a parameter in groundwater); • Action levels for evaluation or response actions.		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Critical activities during remediation

Critical activities during remediation	Aim and most relevant elements of activity
Installation of systems for management or isolation or in situ remediation	Affix systems (withdrawals, cleansing, retaining walls) needed to create the desired (management) situation
Controlling of operating systems	Assess whether commissioned systems comply with technical requirements
Sampling of excavated material	Assess potential reuse options of excavated material. Classify according to HWR (2008) to determine hazardous waste
Assessing excavated material for processing capabilities	Clear and correct manner of assessment
Sampling of air or water	Correctly perform sampling and analysis of effects on environment
Assessing the processing capabilities of air or water (discharge, purify)	Correct and honest manner considering possible processing options based on sampling results
Checking progress of remediation measures	Clear management of the implementation process on quality, quantity and time
Recording of and approving delivery of the work undertaken	Clear determination that meets objective or design work carried out and change (transfer) responsibilities
Documenting of agreements prepared during execution of remediation measures (technical, organizational, financial)	Clear commitment of appointments, arguments which may lead to changes to the original plan of specifications and conditions
Final check of excavated material (soil and groundwater)	Clear provision end situation
Evaluation of work undertaken	Interpretation and assessment of work undertaken, as well as the end result achieved in relation to objective of the remediation
Preparing remediation evaluation report	Clear documentation of basic information and information during the execution and outcome of the remediation

Critical activities during remediation	Aim and most relevant elements of activity
Assessing whether management or post remediation activities are needed	Assess whether remediation can be considered as completed or that the after-care phase must be restarted or management
Commissioning of systems	Set of systems that these both individually and jointly meet the technical and environmental conditions for the management and aftercare
Assessing need for modification of systems	Assess whether and which additional measures are needed to systems individually, or collectively, to work better
Drafting of post remediation programme	Picture of programmatically monitoring, maintenance and replacement activities
Determining restrictions for land use	Unambiguous picture of restrictions as a result of measures selected must be made to the use of the location
Drafting report on post remediation activities	Unambiguous commitment of basic information, objective and approach/programming during post remediation phase
Running post remediation programme	Structured system to perform work to maintain and monitor for proper operation
Evaluation of results of implementation programme	Interpretation and evaluation of work carried out and the results obtained in relation to objective
Provision necessary modifications work, installations or objective	Assess whether and which additional measures are needed to meet the objective of ensuring better, or to what extent adjustment of the objective is necessary
Determining progress or end of management or post remediation phase	Unambiguous determination of the status of the project in relation to the objective

Volume II

8.3-c Checklist remediation evaluation report

Volume II-8.3-c
Checklist Remediation evaluation report

1 Introduction

This information is most relevant for Task 8.3, Execution, supervision and verification remediation works, and for Step 9, Approval remediation completion.

2 Checklist Remediation evaluation report

The checklist below provides the elements that should be included in the Remediation evaluation report. For specific sites some of the elements can be found not applicable. The checklist may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the remediation	
Date of recording	
Recording official	

Content of Remediation evaluation report	**Obligatory**	**Status**	**Comments**
Introduction and background information			
Site metadata (e.g. name, owner, address, GPS-coordinates, site plan and size)	Yes		
Reason for the remediation	Yes		
Summary of the previous investigations and the situation of the contamination at the site (description of history of the land use and the conceptual site model with the applicable combinations of source-pathway-receptor)	Yes		
Agreed remediation objectives and target values	Yes		
Overview of the relevant permits and licenses	Yes		
Summary of the remediation strategy	Yes		
Summary of the intended activities during verification according to the agreed verification plan, including methodologies used for data collection and interpretation	Yes		
Information of the parties involved in the remediation process and their roles	Yes		
Remediation process			
Selected remediation option and specific techniques used	Yes		
Sequential overview of performed remediation activities and parallel supervising and verification activities	Yes		
Summary of incidents and performed mitigating measures	If applicable		
Summary of deviations from the original remediation plan and performed mitigating measures. Including analyses of technical (remediation goal and levels), financial (development of costs compared to the initial cost estimate and	If applicable		

Content of Remediation evaluation report	Obligatory	Status	Comments
contracted activities; note for evaluation purposes only to optimize future site remediations), legal (e.g. site reuse restrictions) and organisational aspects (consequences for post remediation).			
Results of the remediation: ◦ volume of waste, soil or sediment removed or treated; ◦ volume of groundwater or surface water removed or treated; ◦ volume and quality of (liquid) waste transported off-site; ◦ volume and quality of material imported to the site; ◦ data on the quality of capping layers or barriers (including depth, thickness, permeability); ◦ information on permanent remediation installation (for in-situ treatment or containment of the contaminated site); ◦ Annexes with the original test results, photographs, drawings, measurement results, registration documents etc.	All elements that are applicable		
Results of verification measurements (e.g. sampling of extracted material or sampling of pit wall)	Yes		
Results of monitoring of the remediation progress or the attainment of remediation target (e.g. testing surface water or groundwater quality)	If applicable		
Results of the monitoring to demonstrate compliance with health, safety and environmental requirements (according to the health and safety plan and the regulatory permits, licenses and consents)	Yes		
Conclusion on the remediation results			
Description of the situation after completion of the works, supported by a review of the conceptual site model and a description of the rate of contaminant mass reduction and/or removal	Yes		
A conclusion on the effects of deviations of the performed activities, related to the activities as planned in the DPR	If applicable		
Clear conclusion on whether the remediation objectives have been met	Yes		
Identification of the need for post remediation action, and if that is the case, description of monitoring and maintenance requirements to ensure that the performed remediation action remains effective and that the residual contamination will not cause risks for human health or the environment	Yes		
Restrictions to future land use and activities	If applicable		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

9-a Checklist review and approval Remediation completion

Volume II-9-a
Checklist review and approval Remediation completion

1 Introduction

This information is most relevant for Step 9, Approval remediation completion. The results of the remediation have been described in an evaluation (or clean-up) report which is to be reviewed by the competent authority to prepare the decision by the appropriate official. The checklist below provides the points of attention for the review.

2 Checklist review and approval Remediation completion

The checklist below can be used to review the remediation evaluation (clean-up) report. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the remediation	
Date of recording	
Recording official	

No.	Topic		Obligatory	Status	Comments
1	Checklist Remediation evaluation report	Evaluation on whether the Remediation evaluation report meets the requirements of the Checklist Remediation evaluation report (Volume II-8.3-c)	Yes		
2	Verification of the remediation	Results of the verification of the remediation results by an independent third party	Yes		
3	Skills and accreditations	Evaluation on whether the specialized agency or consultant responsible for the preparation of the Remediation evaluation report meets the required skills and accreditations	Yes		
4	Validity of values	When doubting results: cross-check third party values	If necessary		
5	Stakeholder rights and interests	Evaluation on whether the stakeholder rights are guaranteed. A thorough stakeholder involvement offers a good basis for securing stakeholder warranties	Yes		
6	Long term guarantees A B C D	Evaluation if the Remediation evaluation report offers adequate long term guarantees for risk protection and liability. Aspects involved are: Technical aspects Legal aspects Financial aspects Management aspects	Yes		
7	Conclusion	Can remediation completion be approved? If not, which information has to be provided or which activities have to be carried out?	Yes		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

10-a Checklist Post remediation plan

Volume II-10-a
Checklist Post remediation plan

1 Introduction

This information is most relevant for step 10, Post remediation plan (PRP).
Such a plan is required only when a remediation is completed while leaving residual contaminations at the site. In such cases site use restrictions are likely to be in force, and technical measures may be necessary to prevent future human and ecological risks and risks of spreading of the residual contaminations.

The post remediation plan describes all the technical and supporting management activities such as monitoring, maintenance, repairs and corrective actions to keep a remediated site in such a state as to prevent future risks. The post remediation plan should provide for a long term guarantee to the competent authority for a long lasting and adequate risk control.

The checklist below provides a comprehensive overview of elements a full scale post remediation plan may contain. The checklist indicates for every element whether it is obligatory. The post remediation plan is forwarded to the competent authority for approval.

2 Checklist Post remediation plan

Site ID (Name User and Owner, Address, GPS-coordinates)	
Summary of Post remediation plan	
Date of recording	
Recording official	

No.	**Topic**		**Obligatory**	**Status**	**Comments**
1	**Conditions and basic data**				
	A	Description of the site and the already executed assessment and remediation steps. What was the initial remediation target and what has been the result of the remediation.	Yes		
	B	Delineation of the contamination still present at the site, based on the authorized final cleanup report. This should include the Conceptual Site Model and, if available, a model describing the geohydrology and geographical distribution of the contamination.	Yes		
	C	Description of and data on the post remediation measures. This should include the objective and technical aspects of the remediation including applicable drawings with all technical details (e.g. a cross section drawing of the composition of a cover layer; a map with the precise situation of monitoring wells with indication of depth of the wells).	If applicable		
	D	If applicable a prognosis on the functioning of the post remediation measures over time and an overview of processes that may affect this functioning in the future (e.g. for a cover layer the possibility that degradation occurs due to specific forms of land use).	If applicable		

No.	Topic		Obligatory	Status	Comments
	E	Site use restrictions related to the contamination still present and related to the post remedial activities. These restrictions have to be taken into account both on the site itself as well as outside the site.	Yes		
2	**Methodology for development of the PRP**				
	A	Description of the post remediation measures.			
	B	Overview of critical deviation points and action levels to be developed in a set of clear criteria for action (e.g. the depth of a cover layer after remediation was 1.5 meters. In that case the action level can be 1.3 meters. If the result of monitoring indicates a depth of 1.2 meters at a certain point an action has to take place).	Yes		
	C	Description of the post remediation measures and if applicable associated maintenance.	Yes		
	D	Monitoring and maintenance program, developed on the basis of: • the forecast on the functioning of the post remediation measures and the processes that may affect this functioning. The effects of seasonal variations are taken into account; • applicable permits; • Site (re)use and/or (re)development activities.	Yes		
	E	The program describes the sampling, inspection and/or measuring program (only if applicable): • the quality of the soil, (ground)water, air and/or sediments. The effects of spatial variation in monitoring data are taken into account; • the quality and functioning of the post remediation system and checks on specific equipment.	If applicable		
	F	Calamity plan, describing actions in case of emergencies (e.g. change in groundwater flow direction leading to a situation where polluted groundwater will flow in the direction of houses leading to the action of prevention measures on evaporation of volatile components from soil. Another example is the erosion of a cover layer leading to a situation where contact of people with contaminated material can take place again. This leads to an action to restore the cover layer).	Yes		
3	**Analysis and evaluation**				
	A	Description of the status of the post remediation situation (i.e. the post remediation system and its delineation) at the time of writing the PRP, including deviations from the situation as described in the authorized final cleanup report.	Yes		
	B	Evaluation of the deviations in the post remediation situation described above. This should include the description of mitigating measures to restore the original situation in case of non critical deviation points and suggestions for implementation of measures to correct critical deviation points.	Yes		
4	**Management and finance**				
	A	The responsible party including contact information	Yes		
	B	Organisation of tasks and responsibilities	Yes		
	C	Planning of all activities	Yes		
	D	Procedure in case of violation of site use restriction or intended site use changes (e.g. redevelopment)	Yes		
	E	Cost estimation of the various activities	Yes		

Explanatory Notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II

10-b Checklist review and approval Post remediation plan

Volume II-10-b
Checklist review and approval Post remediation plan

1 Introduction

This information is most relevant for Step 10, Post remediation plan. The report of the Post remediation plan is to be reviewed by the competent authority to prepare the decision by the appropriate official.
The checklist below provides the points of attention for the review.

2 Checklist review and approval Post remediation plan

The checklist below can be used to review the Post remediation plan. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main conclusions of the Post remediation plan	
Date of recording	
Recording official	

No.	Topic			Obligatory	Status	Comments
1	Checklist Post remediation plan		Evaluation if the PRP meets the Checklist Post remediation plan (Volume II-10-a)	Yes		
2	Skills and accreditations		Evaluation if the specialized agency or consultant charged with the design and drawing of the PRP meets the required skills and accreditations	Yes		
3	Stakeholder rights and interests		Evaluation if the stakeholder rights are guaranteed. A thorough stakeholder involvement offers a good basis for securing stakeholder warranties	Yes		
4	Long term guarantees		Evaluation if the PRP offers adequate long term guarantees for risk protection and liability. Aspects involved are:	Yes		
		A	Technical aspects			
		B	Legal aspects			
		C	Financial aspects			
		D	Management aspects			
5	Conclusion		Can Post remediation plan be approved? If not, which further information is required?	Yes		

<u>Explanatory Notes:</u>
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: remarks to be entered by reviewer on the results for this topic

Volume II
11-a Checklist Post remediation status report

Volume II-11-a
Checklist Post remediation status report

1 Introduction

This information is most relevant for step 11 Post remediation action.
Post remediation measures may go on for years or even decades. This necessitates updates on the status of the post remediation measures at regular intervals, to be reported in a Post remediation status report. This checklist presents the aspects that should be addressed in such a report. This general checklist should be adjusted for a specific situation.

2 Checklist Post remediation status report

No.	Topic		Obligatory	Status	Comments
1	Introduction				
	A	Client name, site owner, GPS-coordinates, contact details	Yes		
	B	Type of contamination and description whether the contamination is present in soil, sediment, surface water or groundwater	Yes		
	C	Cause and goals for activities and summary of the Post remediation implementation plan (PRIP) applicable for the site	Yes		
	D	Definition of assumptions, including general assumptions described in the Post Remediation Plan (PRP) and translation to the PRIP's			
	E	Status of the remediation measure and contaminations as described in the latest Remediation works report or if more recent the latest PRSR including of a description of the optimized processes implemented since the latest PRSR	Yes		
	F	Report reading instructions	Yes		
2	Background information				
	A	Site metadata, like site address, surface area, site owner name and contact details, present and intended future use, land register details and geographical coordinates			
	B	Reference to the authorized final cleanup report, including its title, author, project number and date), and data on the listing of the site in the NPRPS, including the relevant formal listing decision	Yes		
	C	Historical data and site description, including type of (past and current) industrial activities and site assessments. Of the latter, data should be included on the title, consultant, project number, date and the assessment's framework	Yes		
	D	Detailed description, including maps and soil profiles, of the remaining contamination, for soil, sediment, surface water or groundwater. This should include data on the type of contamination, its geographical distribution, (maximum) measured values and a reference to contamination map(s)	Yes		
	E	Detailed description of technical and management measures and necessary technical equipment	If applicable		
	F	Description of site use and site use restrictions	Yes		
	G	Description of the site ownership legal situation	Yes		
	H	A list of all post remediation measures stakeholders, including the names of the organizations, contact details, and names of contact persons	Yes		
	I	Description of general organizational aspects	Yes		
	J	Description of necessary permits and exemptions	Yes		
	K	Referring to the Post remediation plan and the approval of it by the authorities	Yes		

	L	Clear definition of the boundaries where the post remediation activities are related to	Yes		
	M	Referring to previous PRSR's	Yes		
3	Implementation of post remediation activities				
	A	Chronological description of the executed activities	Yes		
	B	Results of the monitoring (measurements and observations with indication of parameter, time and place, referring to maps of the monitoring system). In annexes of the PRSR all detailed documentation should be added	Yes		
	C	Conclusions on changes in e.g. concentration values in groundwater or direction of groundwater flow, referring to action values	Yes		
	D	Executed repair, maintenance or mitigating measures of non critical deviation points	Yes		
	E	Bottlenecks which have proved to be and description of the executed actions after discovery of these kind of occurrences			
	F	Critical deviation points and suggestions for mitigating measures including technical, financial, time and organisational aspects	Yes		
4	Conclusions and recommendations				
	A	Evaluation of the results of the post remedial activities referring to the intention and to the action levels as described in the PRP	Yes		
	B	Critical or non critical deviations which have occurred during the post remediation period. Evaluation of the cause of these deviations and suggestions for mitigating measures	If applicable		
	C	Suggestion for possible adjustments in the post remedial activities	If applicable		
	D	Suggestion for exit of post remediation phase including data or procedure proving the validity of this exit	If applicable		

Explanatory notes:
Status: yes (information available), no (information not available), action (essential information, must be collected)
Comments: possibility for remarks by reviewer on the results for this topic

Volume II

11-b Checklist review and approval Post remediation status report

Volume II-11-b
Checklist review and approval Post remediation status report

1 Introduction

This information is most relevant for Step 11, Post remediation action. The results of the post remediation action have been described in a Post remediation status report (PRSR) which is to be reviewed by the competent authority to prepare the decision by the appropriate official.
The checklist below provides the points of attention for the review.

2 Checklist review and approval Post remediation status report

The checklist below can be used to review the Post remediation status report. It may be copied and filled in as if it were a form.

Site ID (Name User and Owner, Address, GPS-coordinates)	
Main results of the Post Remediation action	
Date of recording	
Recording official	

No.	**Topic**		**Obliga-tory**	**Status**	**Comments**
1	Checklist Post Remediation Status Report	Evaluation if the Post Remediation Status Report (PRSR) meets the requirements of the Checklist Post Remediation Status Report (Volume II-11-a)	Yes		
2	Validation of the PRSR	Results of the validation of the PRSR by an independent third party	Yes		
3	Skills and accredita-tions	Evaluation if the specialized agency or consultant charged with the design and drawing of the Post Remediation Plan meets the required skills and accredita-tions	Yes		
4	Validity of values	When doubting results: cross-check third party values	If neces-sary		
5	Stakeholder rights and interests	Evaluation if the stakeholder rights are guaranteed. A thorough stakeholder in-volvement offers a good basis for securing stakeholder warranties	Yes		

6	Long term guarantees	Evaluation if the Post Remediation Plan offers adequate long term guarantees for risk protection and liability. Aspects involved are:	Yes		
	A	Technical aspects			
	B	Legal aspects			
	C	Financial aspects			
	D	Management aspects			
7	Conclusion	Can Post remediation activities be approved? If not, which information has to be provided or which activities have to be carried out?	Yes		

National Program for Rehabilitation of Polluted Sites in India

Guidance document for assessment and remediation of contaminated sites in India

Volume III – Tools and manuals

1st Edition, December 2015




Ministry of Environment, Forest and Climate Change
Government of India

Volume III

Introduction and contents

Introduction to Volume III of the Guidance document for assessment and remediation of contaminated sites in India

This document encloses Volume III of the Guidance document for assessment and remediation of contaminated sites in India.
In this Guidance document the technical aspects of the entire process of intervention in a contaminated site, from its earliest identification to post remediation measures, is described in a sequence of fourteen distinct Steps. This set of Steps covers all activities that are performed in dealing with such a site. Wherever applicable, this Guidance document refers to these fourteen Steps. The same Steps, with identical descriptions, are also used in correlation with the non technical aspects, i.e. legal, financial and institutional, of dealing with polluted sites.

The fourteen Steps are visualised in figure III.1 below.

Figure III.1 The fourteen Steps in the site assessment and remediation process

Identification	Planning	Implementation	Post remediation
• Step 1: Identification of probably contaminated sites • Step 2: Preliminary investigation • Step 3: Notification of polluted site • Step 4: Priority list addition	• Step 5: Remediation investigation • Step 6: Remediation Design, DPR • Step 7: DPR approval and financing	• Step 8: Implementation of remediation • Step 9: Approval of remediation completion	• Step 10: Post remediation plan • Step 11: Post remediation action • Step 12: Cost recovery • Step 13: Priority list deletion • Step 14: Site reuse

This Guidance document is organised as a set of documents, arranged in three Volumes:
Volume I Methodologies and guidance
Volume II Standards and checklists
Volume III Tools and manuals

Volume I is the core of the Guidance document set. It presents guidance and instructions as to how to perform each of the fourteen Steps in the site assessment and remediation process. The correlation among the Steps is shown, to enable the user to see what happened before the Step he is involved in and what should happen after completion of that Step. Centred around a concise description of actions to perform the Step the user is involved in, the guidance details aspects for an effective performance, like data needed and where these may be found, and control mechanisms. Wherever relevant, the guidance includes references to Volume II and III and to websites and documents. Volume I is set up in such a way that it may be used in capacity building. It also includes an introduction for aimed at decision makers.

Volume II contains reference data in various forms. Engineers dealing with contaminated sites may use Volume II on a day to day basis to refer to data, standards, criteria and checklists. Every one of these is linked by a reference to one or more descriptions of Steps in Volume I.

This **Volume III** contains more extensive data like technical manuals. Examples of manuals presented in Volume III include a Site Inspection Protocol, points of attention for fieldwork and laboratory testing, an overview of available remediation techniques, and methods for the evaluation of remediation options. Like Volume II, Volume III is intended for day to day reference by engineers dealing with contaminated sites.
This Volume III document should be used in conjunction with the other two Volumes.

Contents of Volume III

Volume III
2.1-i Site Inspection Protocol

Volume III-2.1-i
Site Inspection Protocol

1 Introduction

The Site Inspection Protocol (SIP) provides comprehensive information on preparation, execution and reporting of a preliminary site assessment.
This information is therefore most relevant for Task 2.1 Preliminary site assessment but provides valuable information for Step 1 Identification of probably contaminated sites and Task 2.2 Preliminary site investigation and Task 5.1 Detailed site investigation as well.

This Site Inspection Protocol (version December 2015) is one of the reports by COWI-consortium resulting from the assignment ‘Inventory and mapping of probably contaminated sites in India’ as part of the NPRPS.

2 Site Inspection Protocol

The SIP document is included in this Guidance document on following pages.

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DECEMBER 2015
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

INVENTORY AND MAPPING OF PROBABLY CONTAMI-NATED SITES IN INDIA

SITE INSPECTION PROTOCOL (SIP)

PROJECT NO.	A019251
DOCUMENT NO.	25
VERSION	001
DATE OF ISSUE	30 December 2015
PREPARED	B. v. d. Enden, TJR
CHECKED	TJR, MvV, SV
APPROVED	TJR

CONTENTS

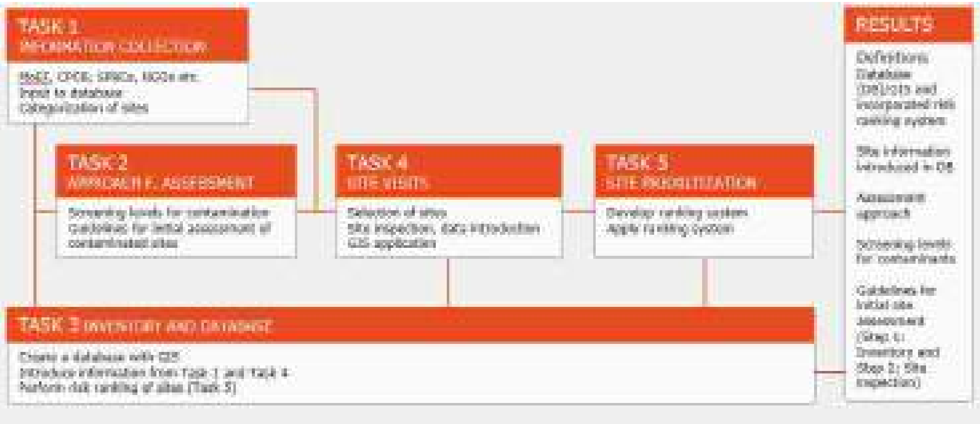
APPENDICES

1 Introduction and Objective

The current Report provides the "Site Investigation Protocol" for the project *Inventory and Mapping of Probably Contaminated Sites In India*, which was awarded by the Ministry of Environment and Forest to a Consortium consisting of COWI as lead partner in association with KADAM, Witteveen+Bos and Tauw as sub-consultants. The Project is funded by the World Bank (WB). Our work is coordinated with the other two assignments of the National Programme for Rehabilitation of Polluted Sites (NPRPS); Assignment 2: the Development of Methodologies for NPRPS and Assignment 3: Development of National Programme for Rehabilitation of Polluted Sites.

The site inspection is a field visit to observe the site and the potential sources of contamination (on-site reconnaissance) and to undertake a perimeter survey of the facility as well as a survey of the local site environs (off-site reconnaissance). During this site inspection information is obtained to fill the gaps and the existing available information is verified.

The Site Inspecton Protocol is a part of Task 2 in the project and has been used at 100 inspected sites in Task 4 of this assignment, see the relation between the tasks shown in the figure below.



The 14 step

In the National Program for Rehabilitation of Polluted Sites (NPRPS) of Assignment 3 and the Guidance Document for Assessment and Remediation of Contaminated Sites in India (Assignment 2), the entire process of intervention on a contaminated site, from its earliest identification to post remediation measures, is described in a sequence of 14 distinct steps. This set of steps covers all activities that are performed in dealing with such a site. Wherever applicable, this Site Inspection Protocol refers to these 14 steps.

The 14 steps are visualised in Figure 1-1. A more detailed description of the 14 steps is presented in our Task 2 Report.

Identification	Planning	Implementation	Post remediation
› Step 1: Identification of probably contaminated sites › **Step 2:** **Preliminary Investigation** › Step 3: Notification of polluted site › Step 4: Priority list addition	› Step 5: Remediation Investigation › Step 6: Remediation Design, DPR › Step 7: DPR approval and financing	› Step 8: Implementation of remediation › Step 9: Approval of remediation completion	› Step 10: Post remediation plan › Step 11: Post remediation action › Step 12: Cost recovery › Step 13: Priority list deletion › Step 14: Site reuse

Figure 1-1 The 14 steps

Step 2

The purpose of the Preliminary Investigation (Step 2) is to establish whether or not a site should be regarded as a contaminated site. This Step 2 is divided into two Steps: Preliminary Site Assessment (Step 2.1) and Preliminary Site Investigation (Step 2.2).

The objective of the Preliminary Site Assessment (Step 2.1) is to focus, as quickly as possible, on imminent threats to human health and/or the environment, to verify if the site is a contaminated site. Step 2.1 includes a desk top study, a site inspection with limited sampling and a brief reporting. Step 2.1 builds on information obtained in Step 1 Identification of probably contaminated site, for the specific sites assessed in Step 2.1.

The objective of the Preliminary Site Investigation (Step 2.2) is to identify all sources of contamination and the relevant pathways linking them to the receptors of concern. Step 2.2 includes planning of the investigation strategy, fieldwork with soil and water sampling and analysis, and reporting. Step 2.2 builds on information obtained in Step 2.1 Preliminary Site Assessment.

This Site Inspection Protocol is a guidance document for how to conduct Step 2.1 (Preliminary assessment). With reference to the 14 steps process for identification and assessment of contaminated sites, the frame for Step 2.1 can be illustrated as in Figure 1-2.

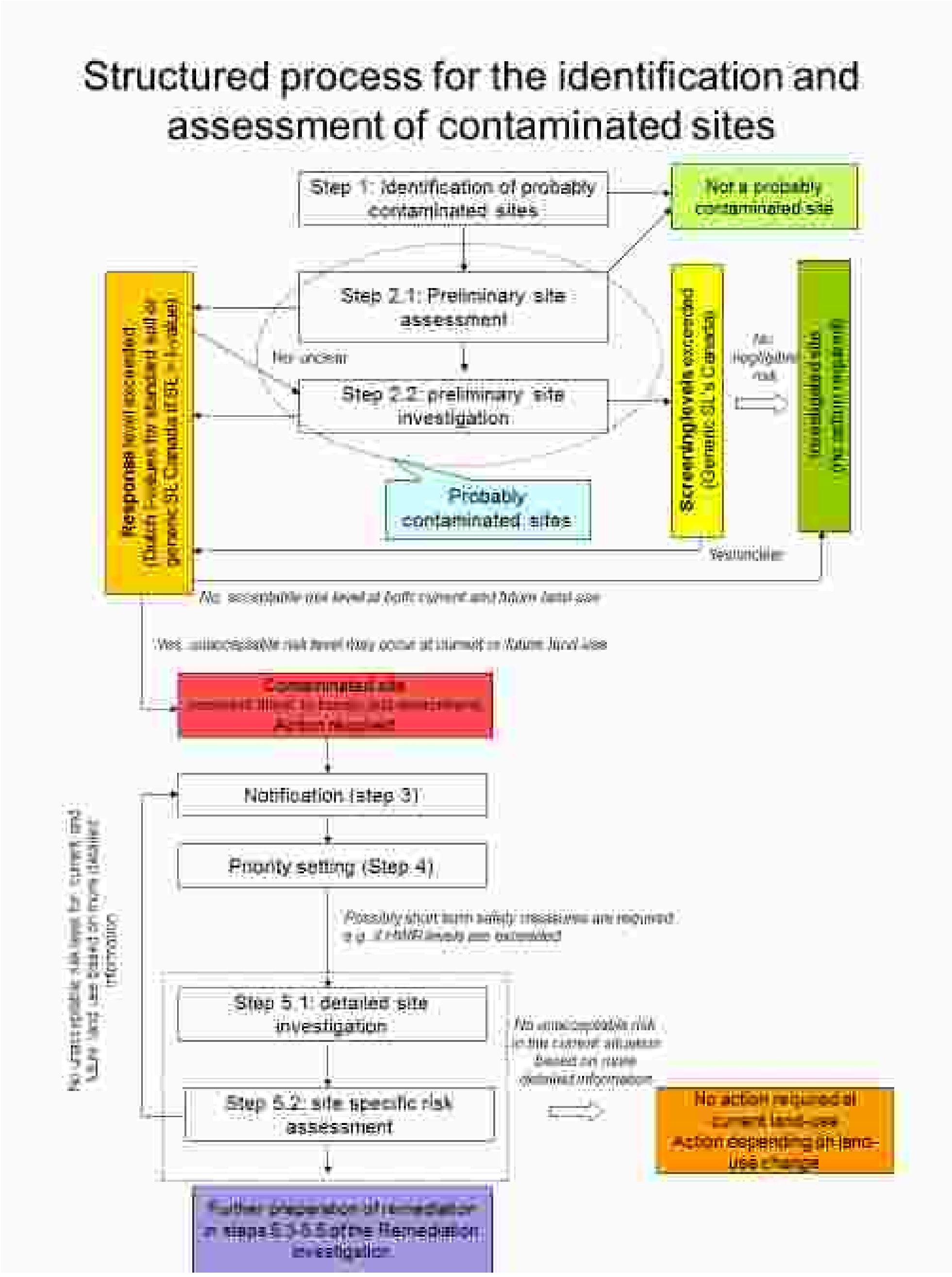
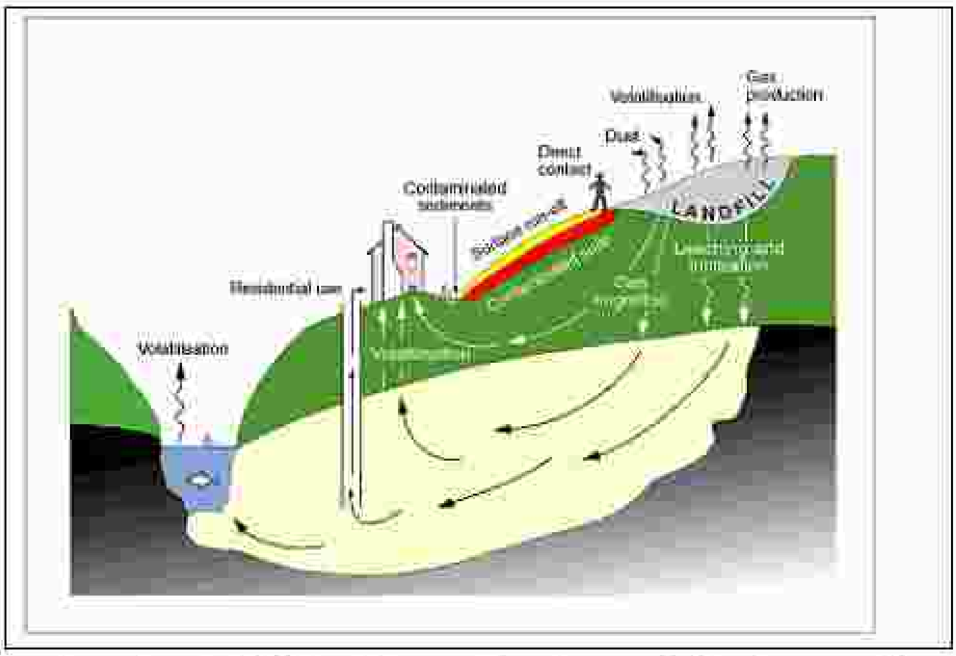


Figure 1-2 Structured process

Site inspection

A site inspection is carried out to verify the information of the desk study including a field visit to visually observe the site and its environs and to collect additional information to supplement the initial assessment under Task 1 (Step 1).

The overall approach for the Site Inspection is to gather information to set up a Conceptual Site Model (CSM). Such a model is developed by integrating as much relevant information on the contaminant situation as possible. This helps to understand the mechanics of the site, and may result in an image like the one in Figure 1-3.



Source: Petts, J. and G. Eduljee. Environmental Impact Assessment for Waste Treatment and Disposal Facilities, p. 229. John Wiley and Sons, Chichester, 1994

Figure 1-3 Conceptual site model

The CSM is based on the 'Source – Pathway – Receptor' approach (SPR), see definition below.

Source – Pathway – Receptor
Source: An area where a hazardous substance may have been deposited, stored, disposed, or placed. Also, soil that may have become contaminated as a result of hazardous substance migration. In general, however, the volumes of air, groundwater, surface water, and surface water sediments that may have become contaminated through migration are not considered sources.
Pathway: The environmental medium through which a hazardous substance may threaten receptors. The migration and threat potential through the groundwater, surface water, air, and soil exposure pathways is assessed.
Receptor: A physical or environmental receptor that is within the receptor distance limit for a particular pathway. Receptors may include wells and surface water intakes supplying drinking water, fisheries, sensitive environments, and resources.

The site investigation includes:

- On-site reconnaissance: This gives the opportunity to visually observe the site and the sources.

- Off-site reconnaissance: An off-site reconnaissance typically includes a perimeter survey of the facility and a local site environs survey.

- Limited sampling: at the locations where main sources of contamination and relevant pathways to possible affected receptors are expected, limited sampling and testing is carried out.

- The results are compared with the Screening and Response levels and a conclusion is drawn as to whether or not the site should be regarded as a contaminated site. Recommendations on the necessity to carry out preliminary site investigation (Step 2.2) and specific aims of that investigation are presented.

- Reporting of results of the preliminary site assessment and review of the report.

Responsible Parties

This activity is typically carried out by technical specialists from the specialized agency/consultant appointed to carry out the preliminary investigation. The work should be supervised by a senior colleague, and close cooperation with the competent authority is necessary to collect important information during the desk study and to prepare the site inspection and sampling.

The team involved should demonstrate in-depth knowledge and experience in the assessment of contaminated sites, including interpretation of topographic and geological maps and reports. The field work team should have relevant expertise, experience and skills for the site inspection and sampling. The laboratory work has to be carried out by an accredited laboratory.

The guidance for conducting a Site Inspection is described in the following chapters.

2 Preparation before site inspection

Before visiting a site the following preparations must be made.

Step 1 Arrange access

Coordinate your site visit with the project coordinator to make sure access to the site is arranged. Identify a local contact or guide. Discuss any potential health and safety issues with regard to the site.

Step 2 Make arrangement with important stakeholders

Try to make arrangement with important stakeholders (e.g. Site owner/operater, Key State/Municipal officials, Key NGO Agency, Local Health Facility Director).

Step 3 Review the site and make a work plan

To prepare for the site reconnaissance, review what is known about the site and what remains unknown according to the Data Sheet in Task 1 (see example of completed Data Sheet in Appendix E).

Review the results of the desk study which is carried out in Step 1 of the 14 steps as described in Section 1 in the Guidance Document of the Assignment 2, Methodologies for the NPRPS, Volume Volume II-1-a (Petition format) and in Volume II-1-b (Checklist).

Of special interest is information about previous investigations at the site to see if there are available and reliable data available, primary data which can be used in the assessment of the site. Sampling points (on site/off site) should be marked on a map and primary data should be illustrated in a table. The below points should be considered when assessing existing primary data:

› Determine what data are available;
› Evaluate purpose and scope of previous investigations;
› Review sampling locations, dates, depths, and sample descriptions;
› Evaluate the sampling results and hazardous substance concentrations;
› Review field preparation and collection techniques for previous samples;
› Review available laboratory documentation;
› Assess usability of previous primary data.

The available reviewed information and the newly collected information can be summarised in a table, and information gaps should be indicated before the site inspection is carried out (reference to Appendix F in the SIP and Appendix E Section 2 SIP Form: Overall assessment of data and data gaps).

Examine available maps, such as from Google Maps, Google Earth, Bing Maps or government sources, to familiarize yourself with the area and key features such as the locations of roads, residential areas, industrial or mining areas and water bodies. Look for sampling data from other research projects.

Based on all the compiled information, a work plan should be made prior to the site inspection. This work plan should include all reconnaissance activities and identify the specific information to be collected e.g. sampling from drinking water wells, noting the local hydrogeology, estimating the population at risk, interviews with specific stakeholders (such as occupants, current or former owners, neighbours, manager, employees and government officials) etc.

Step 4 Prepare your equipment

The following equipment is required:

- Camera (check batteries);
- Notepad, site review questionnaire and pen. Please take detailed notes;
- Map of the site (printed from Google Maps, Google Earth, Bing Maps or a local map);
- GPS device;
- Personal protective equipment. If you need to purchase protective equipment, please contact the coordinator of the survey team. Safety is very important. Be careful and avoid potentially dangerous situations. See the Health and Safety section for further information.

Step 5 Prepare sampling equipment

The following equipment is required:

- Something to collect samples (auger or shovel, spoon and bottle);
- Storage containers for samples (jars for soil, preserved bottles for water);
- A permanent pen to mark samples;
- A water pump with clean sampling hose or (disposable) bailers;
- Cool box to store samples.

Follow the sample protocol in Appendix A.

The samples should be tested in a laboratory to assess the levels of contamination. Laboratories should operate in accordance with specific accreditation criteria (refer to Checklist prequalification for site investigation, Development of Methodologies for NPRPS, Guidance Document, Volume II-2.1-a).

3 Health and safety guidelines

3.1 Introduction

This Chapter provides an overview of the health and safety guidelines which should be followed before, during and after the site visits by people involved.

Before each site visit the coordinator of the team must:

› evaluate potential health and safety hazards;
› identify appropriate controls and precautions to eliminate or reduce risks;
› brief other involved parties coming to the site on general and any specific health and safety requirements.

3.2 Risk screening

Before conducting a site visit, the coordinator and the team itself must identify the potential hazards that they may encounter at the site. The different types of potential hazards are included in Table 3-1.

Table 3-1 Potential hazards

Type of hazard	Examples	Notes
Chemical hazard	Chemical pollutants present at the site	Awareness of the presence of hazardous waste and pollutants is very important. Review previous studies or publications related the area, identify potential sources
Physical hazard	Noise, slips, falls, climate conditions, sharps and needles from hospital wastes	Take into account the layout and state of the site, particularly any holes, excavations, buildings etc. Attention should be paid to expected local weather
Biological hazard	Bacteria, viruses, parasites, animal bites, hospital waste (blood and other body fluids, bandages, etc.)	Awareness of the presence of dangerous animals (e.g. snakes, scorpions) is very important. Sewage water and dead animals are a source for pathogens and bacteria

Once hazards have been identified, the coordinator of the team must estimate the probability that the expected extent of exposure to the identified hazards will put the inspection team at significant risk. The principal pathways of exposure at contaminated sites are normally ingestion, inhalation and direct contact, but other possible exposures should be considered.

In addition, the coordinator of the team must determine what measures the team must take to reduce the probability that the exposure to these hazards will cause injury or endanger wellbeing (such as wearing personal protective equipment, etc.).

N.B. Sites with ***radioactive waste or possible radiation exposures*** are excluded from site visits because these sites require specific health and safety measures.

3.3 Personal protection equipment (PPE)

The inspection team must have access to essential personal protective equipment (PPE). The coordinator of the team must identify and check the correct use of appropriate PPE during site visits.

Basic equipment includes:

- Boots (closed shoes are required – open toe shoes are not allowed); Its recommendated to use footwear (shoes, boots, wellingtons) according to e.g. European S3 standard (200 joule toe cap protection, fully enclosed heel, antistatic properties, energy absorption of seat region, water penetration and water absorption resistance, sole penetration resistance, cleated outsole, http://en.wikipedia.org/wiki/Steel-toe_boot) . Especially on waste dumpsites, mining tips and scrapyards, sole penetration resistance is essential. Also, boots above ankle height reduce snake bite risk by approximately 90%;
- Protective clothing such as pants with long legs and long-sleeved shirts are required;
- Dust mask must be worn whenever there is potential exposure to (hazardous) dust; Reference to suitable mask types, e.g. as published by Draeger (see [1] e.g. http://www.draeger.ae/media/10/03/67/10036736/filter_selection_guide_br_9046529_en.pdf , p. 6).
- Goggles or safety glasses must be worn whenever there is the presence of particles in the air that may damage the eyes (for example, significant amounts of dust) or when there is the risk of splash or splatter of contaminated substances;
- Gloves, if touching, picking up or sampling of any material, soil or water.

Other PPE may be identified as relevant to a specific site. PPE should be inspected before every site visit and be cleaned, repaired or replaced if needed.

3.4 Site visit

Before starting each new day of site inspections, a toolbox meeting is given by the coordinator of the team. During these toolbox meetings, safety procedures will be explained to each member of the field team.

During the site visit the team must:

- Wear appropriate PPE (see above);
- Wash hands before eating anything (even if gloves are worn during the visit);
- Not enter confined areas. These are areas large enough for a person to enter, but with limited ventilation and/or limited or restricted means of entry or exit;
- Be cautious in areas that may be slippery due to water, mud, steep slopes, etc.;
- Be cautious if using ladders or stairways that may be unsafe;
- Be cautious in elevated areas;
- Be aware that hazardous material and toxic contamination may look harmless. Allways, take precautions.

Touching or any contact with human and animal fluids and waste, or dead animals, should be avoided during site visits. Bacteria, viruses, parasites can be present in human and animal fluids and waste such as blood, faeces and urine.

After the site visit the team must:

- Wash hands and face before eating anything;

- Change from working clothes and shoes. Take showers before entering into close contact with other people, particularly pregnant women and/or children;

- Clean shoes to remove any mud or soil on them, wear gloves during the cleaning and make sure that the removed soil is collected and disposed of properly or is left at the site;

- Wash clothing before wearing again.

Communicate lessons learned during the site visits to the coordinators from the other teams to prevent future incidents.

4 Existing and general information

Before you start your site investigation, first complete the Data Sheet in Appendix F as well as possible by conducting a desk research..

Make use of internet, Google Earth, the Black Smith Institute inventory (if available) and other sources.

Based on this desk study establish:

› Evaluation of existing data e.g. existing primary data (see Appendix F);

› Assessment of important data gaps which must be obtained in the Site Inspection;

› Assessment of CosC and which contaminants to analyse (based on industry type and available information);

› Initial assessment of samples to be taken, e.g. samples in a known source area or from a drinking water tube/surface water body;

› Identify focus points for Site Inspection e.g. drinking water wells, hydrogeology, population at risc, interview with specific stakeholder etc.

Fill in the following table before your site visit. Use and verify the information available in the Data Sheet.

Data sheet no. #		
1.	**General Site Information**	
1.0	State Name	
1.1	ID number (State-district-xx)	
1.2	Site Name	
1.3	Address (Street, Street number, postal code)	
1.4	GPS coordinates /and elevation (x, y coordinates of the corners of perimeter) - (The coordinates should be written in Geographic latitude and longitude (North and East) for use in India	Location of coordinates is shown on map in section 6

Data sheet no. #		
	throughout the report) (add more points if required)	
1.4.1/ 1.4.2	1	X:
		Y:
	2	X:
		Y:
	3	X:
		Y:
	4	X:
		Y:
1.4.3	Altitude (m above sea level)	
1.6.1	Who is the current owner (name and address)	
1.6.2	Who was the previous owner (name and address)	
1.6.3	What is the current status of contact with owner	
		1=Owner known and in communication with regulator; 2=Owner known but not available/communicating; 3=Owner not known
	Site Access (yes/no, any restrictions?). Will the Consultant have access to the site for field investigations	
	Contact person	
	Phone number	
	What are the available dates / hours to visit the site?	
	Are safety measures required by the owner of the site? If so, which safety measures? Are there any known dangers which a visitor should be aware of like unstable buildings and structures, toxic liquids, holes etc.).	
	Is there a permission to visit / investigate the whole site?	
1.10 + 1.11	**Historical review and overall Site description** Describe historical information about the site (industrial activities, including maps of features of these sites e.g., production area, storage area, underground storage tanks, information on reported spills/dumping etc. Give an overall description of the site including a clear description of the type of site e.g.: i) is the site a point site with former or ongoing industrial activities on the site; ii) is the site an industrial area (with cluster of industries = Area Site) with no clear source of contamination); iii) is the site an area (e.g. waste land/water body/habitation area) where contamination has been spread via effluent or dumping of waste from an industry (or number of industries) which is placed outside the site boundary. Specify if there are any uncertainties with the Site Definition.	
1.16	Extend of data available (if any).	
		A=Almost no information; B=Desk top study performed but no primary data; C=Site

Data sheet no. #		
		investigations performed an primary data available; D=Ongoing remediation; E=Other (specify).
1.17	Previous or ongoing remediation activities (if any)	
2.	**Source of contamination and waste characteristics**	
2.7.1	Give a brief summary of previous investigations performed at the site and in the vicinity (if any). Describe results of soil, air, groundwater and surface water on/off the site (if any). Analysis results should be included. For soil analysis max concentrations in should be reported if possible distinguish between top soil and deeper soil contamination. Depth must always be specified. For groundwater data depth of sample should be reported.	
2.7.2	Compare primary data with SSLs and Response Levels. Calculate the over standard ratio of the maximum concentration level compared to the screening value.	
3.	**Groundwater use and characteristics**	
3.1	Geology at the site. Give an overall description.	 Broad description of the typical stratigraphical sequences from topsoil to deepest aquifer. Based on earlier studies and / or general knowledge.
3.2.1	Hydrogeology - Overall description.	 Describe the depth of aquifers which is relevant for migration of contamination and drinking water/irrigation. The aquifers can be secondary/shallow aquifers and deeper aquifers (primary aquifers). Also, describe soil type of aquifers (sand, clay, bedrock, other) based on earlier studies and / or general knowledge.
3.2.2	Hydrogeology - Groundwater flow direction	 Describe direction for each aquifer(if any information).
10.	**Overall Location and site description**	

#: refer to category in Data Sheet

4.1 Overall assessment of data and data gaps (assessed before Site Inspection)

Item	
Assessment of available data (e.g. analytical results). Can existing data be used to assess present contamination at the site?	
What are the Chemicals of Concern (CoCs)?	
What are the data gaps? (Description of site, location of site, etc.)	
Give an initial assessment of the samples to be taken (soil, groundwater, surface water, other?)	
What are the focus points during the Site inspection?	
Identify important stakeholders who should participate in the Site Inspection	

5 On site reconnaissance

Fill in the following table during your site visit based on interview of the contact person and own observations. Verify the information as is available in the Database.

Take photographs of all relevant observations. In some cases, a photograph is obligatory.

Provide any obtained additional relevant information which cannot be filled into the table with site ID and data number corresponding with the table.

Date and time of site visit	…
Site investigation conducted by	… ….
Spoken with	… …
Weather conditions during visit	…

Data sheet no. 1. #	General site information	
1.15	Operational status	 1 = Active/ongoing; 2 = Closed; 3 = Abandoned; 4 = Other (specify)
1.5.1	What is the current land use?	…
1.5.2	What was the previous land	…

Data sheet no.				
	use?			
1.5.3	What is the future land use (planned)	...		
		1 = Agricultural land; 2 = Waste land; 3 = Water bodies; 4 = Forests; 5 = Habitation settlement (Residential/School/Kindergarten); 6 = Commercial; 7 = Industrial, 8 = Mixed (to be specified for each case) and 9 = Other (to be specified in each case)		
1.7	Name(s) of polluter(s)			
		E.g. Name and address of industry, institution or person who caused the contamination		
1.8	Approximate area of site (m2)	...	m2	
	Built-up area (m2 or percentage of total)	...	%	
	Paved area (m2 or percentage of total)	...	%	
	Non-paved area (m2 or percentage of total)	...	%	
1.9	Topography			
		1 = Water; 2 = Plains; 3 = Mountains; 4 = Hills; 5 = Any other (specify)		
1.10	Type of site			
		1 = “Point”site (single industry/dumpsite); 2 = ”Area”site(Industrial area or estate (cluster); 3 = Any other (specify)		
1.12	Industry type (which have caused contamination)	...		
		(select from Basetable 4 of the Data sheet in Annex F)		
1.13	Period of operation/contamination (year)	...		
		Enter period of operation (from – to) Period of contamination (from – to) based on available information		
1.14	Is the site classified before or after the development of HW rules in 1989 (Before / After)			
2.	**Source of contamination and waste characteristics**			

Data sheet no.			
	Are there dump sites present? Describe	yes / no	....
2.1.1	Physically state of waste as deposited		
		1 = Solid, 2 = Sludge, 3 = Powder, 4 = Liquid, 5 = Gas, 6 = unknown, 7 = Any other (specify)	
2.1.2	Origin of the deposit		
		1 = dump, 2 = leakage, 3 = fluviatile deposit (sediment), 4 = areal deposit, 5 = storage, 6 = Effluent (wastewater) 7 = Any other (specify)	
2.1.3	Position in soil/effluent		
		1 = On the surface; 2 = In the soil; 3 = In effluent (wastewater); 4 = Any other (specify)	
2.1.4	Is there visual contamination		
		Describe visual contamination in soil; groundwater; surface water; effluent	
2.1.5	Is there vegetation stress		
		Describe any sign of vegetation stress	
2.1.6	Area of contaminated soil		
		Area of the above source or area of HW deposited	
2.1.7	Volumen of contaminated soil		
		m3 / mt (source in soil or HW deposited)	
2.1.8	Is the source area delineated		
2.1.9	Area of contaminated groundwater		
		If plume is delineated assess the area of the plume (lengt (m), widht (m) area (m2)	
2.2	Type of contamination according to definition from MoeF		
		1 = Effluent; 2 = Air; 3 = Municipal Solid Waste; 4 = Bio-medical Waste; 5 = Hazardous Waste; 6 = Ship Break Waste; 7 = Any other (specify)	
2.3	"Industrial processes" which caused the contamination (According to Base table 5 of the Data sheet in Annex F)	...	

Data sheet no.					
2.4	Type of hazardous waste				
		According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) - select from Basetable 6 of the Data sheet in Annex F			
2.5	Hazardous Waste Constituents				
		According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) - select from Basetable 7 4 of the Data sheet in Annex F			
2.6	What are the COC's? (use UBI Appendix C)	...			
	What potential sources of contamination are present? Quantify as much as possible (area and/or volume) Describe	....			
	Are there storage tanks present at the site? Specify number, sub surface or on surface, content (chemical) (If specification is available, please add)	yes / no	... (number)	sub surface / on surface / both	content
	Is there visible soil contamination present?	yes / no		Take 1 to 2 samples of most contaminated sites	
	What is the level (intensity) of visible soil contamination?	low / medium / high impact		Take photo	
	What is the scale of visible soil contamination? (percentage of total site size)	< 10% / 10 - 50% / >50%			
	Are the buildings visibly contaminated?	yes / no / NA			
	What is the level (intensity) of the building/ infrastructure visible contamination?	low / medium / high impact / NA		Take photo	
	What is the scale of the visible building/ infrastructure contamination? (percentage of total buildings/ infrastructure)	< 10% / 10 - 50% / >50% / NA			

Data sheet no.				
	Are there materials present which might contain asbestos? (corrugated roofing panels			
	Is the present contamination local (hot spot) or diffuse?	hot spot / diffuse / both / none		
3.	**Groundwater use and characteristics**			
3.2.3	Hydrogeology - Depth to water table (m below subsurface, use wet season estimate).			
		Describe the depth to the water table for each aquifer. Based on local knowledge or information from Ground water Authorities or data from Site Inspection		
3.3	Current and future expected use of any aquifer for groundwater use			
		Describe current and future planned use of any aquifer		
3.4	Is the site within a groundwater recharge zone			
		1 = Area with special drinking water interest (i.e. major aquifer/potable water supply) 2 = Areas with drinking water interest (aquifer with major aquifer potential) 3 = Areas with borderline drinking water interest (minor aquifer/ non potable water		
	Are there groundwater wells present on site? If so what use (consumption / domestic / industrial), what yield?	yes / no	consumption / domestic / industrial	**Take photo**
	Are there indications of groundwater pollution; e.g. smelling wells. If yes, what is the level (intensity) of groundwater contamination (if noticeable)?	yes / no / NA	...	**Take sample**
4.	**Surface water use and characteristics**			
4.1	Any drainage system (run off system) on site	...		
		General description of (drain, trenches, streams) or streams at the site which can transport the contamination outside the premise to surface water bodies		
4.3	Type of Surface water Body			
		1 = Pond (less than 1 hectare), 2 = Small lake (1-10 hectares), 3 = Large lake (more than 10 hectares), 4 = Small river/stream, 5 =		

Data sheet no.					
		Large river, 6 = Wetland, 7 = Other (specify if possible)			
4.4	Any sensitive use of surface water				
		1 = Drinking Water, 2 = Irrigation, 3 = Use in commercial food production, 4 = Water recreational area (e.g. bathing, marina), 5 = Fishing, 6 = Other (specify if possible)			
4.6	Are there signs of flooding? Describe	yes / no	...		
	If so, what is the water table to the surrounding surface? (m below ssl)	... m - ssl			
	Is there any discharge to the surface water visible? Describe	yes / no / NA	...		**Take photo** **Take sample**
	Is the surface water visibly contaminated? Describe	yes / no / NA	...		**Take photo**
5.	**Soil exposure characteristics**				
5.1.1	Access to the site from local communities				
		1 = Site secured and access controlled 2 = Site not secured but access limited 3 = Open site with regular public activity, 4 = Other (specify)			
5.1.2	Is there inhabitation on the site? If so how many people? How many children?	yes / no	... (number)	... (number)	
5.1.3	How many workers are working on site? (Number)	...	Remarks: ..		
5.1.4	Specify other activities if any	...			
	Is there agricultural use at the site (crop growing / keeping of domestic stock)? Describe	yes / no	...		
6.	**Air exposure characteristics**				
6.1	What are the prevailing wind directions?	N / NE / E / SE / S / SW / W / NW / unknown			
	Is there a noticeable (smell) /bad air quality at the site?	yes / no	...		

Data sheet no.			
	Dust visible? Describe		

#: refer to category in Data Sheet

6 Off site reconnaissance

After the site visit ,make a tour around the site to assess the environmental impact on the surroundings. Fill in the table below based on your observations and possible interviews with local people.

Verify the information as is available in the Database.

Take photographs of all striking and relevant observations. In some cases, a photograph is obligatory.

Provide any obtained additional information which cannot be filled into the table with site ID and data number corresponding with the table.

Data sheet No #				
3.	**Groundwater use and characteristics**			
	Are there groundwater wells present? If so what use (consumption / domestic / industrial).	yes / no	consumption / domestic use / industrial	**Take photo** **Take sample if notice-able pollution is present**
3.5.1	Private wells (distances to nearest well and approximate number of wells within 1 km from the site)	... meters	... (number)	
3.5.2	Public wells (distances to nearest well and number of wells within 1 km from the site)	... meters	... (number)	
4.	**Surface water use and characteristics**			

4.1	Any drainage system (run off system) outside the site	...		
		General description of (drain, trenches, streams) or streams at the site which can transport the contamination outside the premises to surface water bodies		
4.2	Name and distance to nearest surface water body (m)			
4.3	Type of Surface water Body			
		1 = Pond (less than 1 hectare), 2 = Small lake (1-10 hectares), 3 = Large lake (more than 10 hectares), 4 = Small river/stream, 5 = Large river, 6 = Wetland, 7 = Other (specify if possible)		
4.4	Any sensitive use of surface water			
		1 = Drinking Water, 2 = Irrigation, 3 = Use in commercial food production, 4 = Water recreational area (e.g. bathing, marina), 5 = Fishing, 6 = Other (specify if possible)		
	Is there surface water directly next to the site? If so, what type	yes / no	...	
	What distance is the water table to the surrounding surface? (m below ssl)	... m - ssl		
	Is there visible discharge from the site visible? (Describe)	yes / no / NA	...	**Take photo** **Take sample**
	Is the surface water visibly contaminated? (Describe)	yes / no / NA	...	**Take photo and take sample**
4.5	What is the distance to sensitive environments and Wetlands (m)? (Describe)	... meters	...	
5.	**Soil exposure characteristics**			
5.2.1	What is the land use in the vicinity of the site?	1 = Agricultural land; 2 = Waste land; 3 = Water bodies; 4 = Forests; 5 = Habitation settlement (Residential/School/Kindergarten0; 6 = Commercial; 7 = Industrial, 8 = Mixed (to be specified for each case) and 9 = Other (to be specified in each case)		
	North	...		
	East	...		
	South	...		
	West	...		

	Are there crops grown next to the site? (Describe)	yes / no	...	**Take photo**
	Is there domestic stock present next to the site?	yes / no	...	**Take photo**
5.2.2	What is the distance to the nearest habitation? (Describe)	... meters	...	**Take photo**
	Approximate number of people living within 100 meter	... (number)		
5.2.3	Approximate number of people living within 1 km	... (number)		
5.2.4	What is the distance to other sensitive activities e.g. schools, nursery, allotments (m)? (Describe)	... meters	...	
7.	**Socio economic aspects**			
7.1	Describe general socio economic conditions			
		E.g. employment rate, in-come, rate woman/man, rate in age, population density, occupation, alphabetise, religion, value of site/buildings, possibilities of temporary site clearance, social sensibility land user(s),		
7.2	Drinking water source	...		
		Describe drinking water source (e.g. public water supply based on groundwater) for the population in he vicinity of the site (within 1 km)		

#: refer to category in Data Sheet

7 Miscellaneous

1.18	**Complaints**: List any other pending complaints, claims, liabilities, non-compliances, conversations with site personnel or neighbours, and other relevant matters related to soil and groundwater pollution aspects
	Data gaps: List major (if any) data gaps or uncertainties which still occur after the conducted Site Inspections (e.g. insufficient information about geology/hydrogeology)
	Emergency response considerations: List observed conditions that may warrant immediate or emergency action (e.g. heavily contaminated groundwater/surface water used for drinking water, unrestricted public access to exposed hazardous substances etc.)

8 SITE map

Provide a sketch of the site's lay-out (include at least main occurrences and main sources and pathways of pollution):

MAP THE SITE

Draw or copy a map of the site that shows the pollution source, the pathways to humans, the location of your samples and any pollution hotspots, neighborhoods that might be affected, and any other relevant landmarks or sites.

A digital map is preferable, though hand-drawn maps are acceptable.

DIGITAL MAPS

Digital maps can be drawn using bing (http://www.bing.com/maps/), Google Earth or a number of other free software applications.

Bing Maps (*Figure 1*)

1. Right Click on location > "Add a Pushpin" Name and Save thew Pushpin
2. Mark area of contamination using area tool in "My Places Editor"
3. Actions > Export > KML

Google Earth

1. Use Path tool to draw area.
2. Save Path
3. Right Click Path in Places Menu > Save Place As > KML

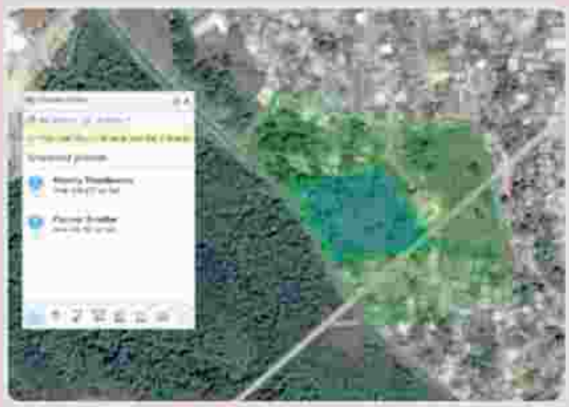


Fig. 1. Created in Bing Maps and exported to KML. This simple map sufficiently demonstrates the pollution source and affected area.

9 Sampling

To make a first assessment of the present contamination, samples will be taken during the site visit. This sampling concentrates on the source of contamination and the water as a pathway. This sampling is meant as a first assessment of the site based on actual concentration levels.

Sampling of source area:

- Samples of soil will be taken at places where contamination is visible/noticeable on the surface or (if no contamination is visible) at the locations where “sources” are most likely, given the (former) activities on the site. In case of surface water, this can also be a sample of the top sediment;
- If a discharge is present, an effluent sample will be taken;
- Surface water samples will be taken if there is clearly a surface water contamination noticeable.

Sampling of pathways:

- Groundwater samples will be taken from tube wells if they are present on the site or in its vicinity.

QC sampling:

- For reasons of quality assurance, a fraction of the samples will be taken in duplicate and sent to a other laboratory (see Section 13.2);
- The sampling procedure should also include the use of trip blank, field blank and equipment blank samples.

Describe the samples taken in the table below. For the sampling protocol, see Appendix A.

Always use the uniform sample coding as described in Appendix A.

The objective of the quantitative analyses is to obtain a first assessment of levels of contamination at the site.

When taking samples, customization of the sampling program (locations and type) is important and must be determined by the expert in the field. Some important considerations are:

- Sample the most visible contaminated media (soil / sediment / water), because this gives a first impression of the levels of contamination;
- If possible, sample areas that can be accessed by humans, exposure of humans is be possible (see Appendix A);
- If present, always take a water sample from (drinking) water wells (if many drinking water wells, give priority to drinking water wells in downstreams areas);
- If it is probable that larger areas of soil are contaminated by non-volatile compounds like metals, TPH and/or PAH, make at least 1 composite sample of the most sensitive area (residential area, playground, agricultural fields) according the protocol in Appendix A.

Other possible locations for sampling of sources and pathways:

- Visual indication of cause of pollution such as the presence of (former) industrial process equipment, storage tanks, broken pipelines, etc;
- Visual evidence of hazardous material by means of colour or odour or the composition of material, or uneven ground surface;
- Reported location with confirmed high concentration levels in previous sampling results;
- Where an incident (spill / uncontrolled release) has occurred identified by a former employee of a company;
- Areas which can easily be accessed by humans and areas of sensitive use (residential, playground, agriculture);
- Drinking water wells downstream of the site (collect groundwater samples to assess if this pathway is contaminated);
- Surface water at or near the site if expected to be contaminated by hazardous waste material;
- At discharge points with noticeable contamination an effluent sample should be taken;
- In cases of sites with effluent discharges a ‘source sample’ should also include a sample of the sediment.

Site ID + number	soil / water	Date for sampling	Targeted or composite	Location (description and GPS coordinates if available)	Parameters analysed	Motivation of sampling *
1.						
2.						
3.						
4.						

*: Motivation (e.g. visible contamination, source area). Must also include information about landuse (only soil) and location of sample (inside/outside the site)

10 Overall assessment of pathways, exposure, impacts and contamination

The initial conclusions from the Site Inspections should be filled into the table below:

Data sheet No #		
8.	**Pathways, exposure impacts and risc from contamination**	
8.1	Potential/observed pathways for spreading of contaminants at the site	
		1 = Groundwater pathway, 2 = Surface Water pathway, 3 = Soil exposure pathway, 4 = Air pathway 5 = Any other (specify)
8.2	Potential/observed exposure to contaminants	
		1 = Direct human contact, 2 = Ingestion (soil, food) 3 = Groundwater use (Drinking water, Irrigation), 4 = Inhalation of polluted air/dust, 5 = Surface water use (drinking water, bathing, fishing), 6 = Sensitive environments, 7 = Other (specify)
8.3	Describe observed impacts (if any)	
		E.g. observed impacts on humans, animals, flora, fauna
8.4	Estimation of population at risk (see Appendix B) <1000 1.000 – 5.000 5.000 – 10.000 10.000 – 20.000 20.000 – 50.000 50.000 – 100.000 100.000 – 200.000 200.000 – 500.000	Specify

Data sheet No #		
	>500.000	
9.1/ 9.2/ 9.3	Typology of contaminated site according to standard, see Appendix D (Note that more than one typology can be applicable): **S-1 Soil phase contaminations (land bound site):** (Subdivided into S1 – a; S1 – b; S1 – c; S1 – d; S1 – e; S1 – f) **S-2 (Solid phase contaminations (water bound site)** **L-1 (Liquid phase contaminations)** (Subdivided into L1 – a; L1 – b; L1 – c; 1 – d) **P-1 Liquid phase related** (Subdivided into P1 – a; P1 – b) **P-2 Groundwater contamination** (Leached or dissolved contaminants) Specify overall typology and, if possible, also subdivision of typology	
	Assessment of contamination from Site Inspection (based on analytical results from Site Inspection – see Section 11 and 12) (Specify most critical contaminants, specify if concentrations exceed SSLs and Response Levels) If lack of data, include results from previous investigations (if any)	Soil: Groundwater: Surface water:

Data sheet No #		
	Conclusion and recommendations: Assess whether or not the site meets the definition of contaminated site. Describe recommendation for the next step in the assessment and remediation process. If the information is too insuffiecient to draw a conclusion, a recommendation for further investigation should be provided.	

#: refer to category in Data Sheet

Comparing testing results with standard

The laboratory testing will result in a list of concentration levels for various parameters/substances. These concentration levels have to be compared with the Screening Levels and the Response Levels, refer to Appendix G.

The outcome of the comparison will determine whether or not the site should be regarded as a contaminated site. The following situations can occur:

› If the contaminants exist at or below Screening Levels, the site cannot directly be regarded as ‘not a probably contaminated site’. This, because of the fact that only a limited number of samples were taken. Further investigation is necessary to assess if there are any further sources of contamination at the site which may cause a risk to present or future land use. This can be done by a preliminary site investigation.

› If the contaminants exist at or above Screening Levels but at or below Response Levels, the site may be determined as 'probably contaminated site'. Then, a preliminary site investigation should be carried out as well. This is because of the fact that only a limited number of samples were taken and there may be other locations on the site where higher concentration of contaminants occur.

› If the contaminants exist at or above Response Levels, the site can be classified as 'a contaminated site'. Often it is not clear, if all sources and pathways have been identified and samples have actually been taken. In that case, a preliminary site investigation is necessary. If it is clear that all sources and relevant pathways have been identified and samples were taken from these points, no preliminary site investigation is necessary. In that case, the site may be notified directly as 'a contaminated site' and prioritisation can take place (Step 3 and Step 4 of the assessment and remediation process, see Section 1).

11 Draft Conceptual Site Model (CSM)

A Conceptual Site Model is a simple, schematized description and/or visualisation of the (assumed) situation of contamination (source, nature and levels of contamination, distribution), the physical system (geology), processes which influence the spreading of contaminants (geochemistry and (geo)hydrology) and receptors of contaminants (land use, threatened objects). The CSM should at least provide understanding of the relevant source - pathways - receptors at the site.

The Guidance Document of the Development of Methodologies for NPRPS, *"Volume III-2.2-I Manual Conceptual Site Model and identifying the Source-Pathway-Receptor (Assignment 2)"* further describes how to develop a Conceptual Site Model and its role in the assessment and remediation of sites. Developing a CSM is an iterative process and acts as baseline for the next step in the investigation chain.

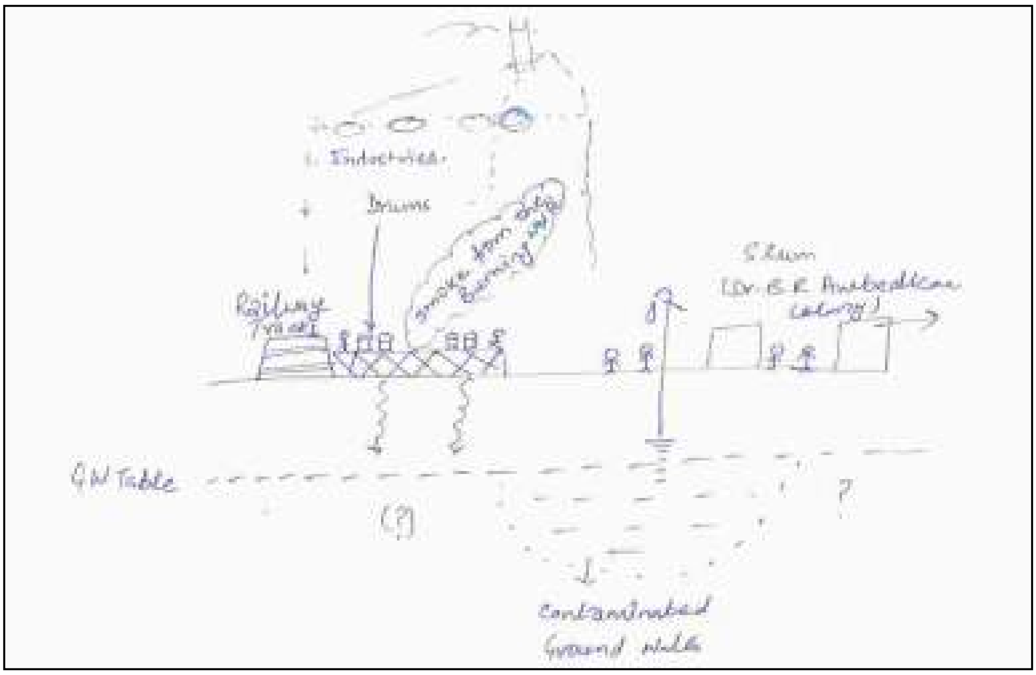
Based on the available information provide a sketch of the site's Conceptual Site Model:

Sketch a 2D cross section, and try to include as much of the following items:

- Source areas
- Plume
- Pathways (groundwater, surface water, soil, air)

- Receptors: Presence of people, physical resources (drinking water wells or surface water intakes), and environmental resources (sensitive environments, fisheries) that might be threatened by release of a hazardous substance from the site.
- Geology
- (Geo) hydrology
- Data gaps.

Example of CSM:



12 Photographic record

Please include several photos that best illustrate the soil and groundwater quality related aspects and issues:

Number	Description	Location

Mark the point of view and number on a printout of Google Earth, Google maps or Bing Maps.

13 Quality assurance and quality control

13.1 Reporting the site visit

After each site visit, the team makes a Site Investigation Form, according to Appendix E.

It is very important that the form is filled in completely, consistently and elaborately.

Draft Forms must be checked by a technical specialists with relevant experience within this field. After processing the comments, the final draft and final version must be checked by a senior specialist by signing the document.

13.2 Laboratory analyses

The laboratory work has to be carried out by an accredited laboratory. Before sampling, it must be ensured that the detection limit is below the screening levels, preferable a factor 10 below the screening level.

If there is doubt about the quality of the analyses, cross-checking of 5% of the samples by a second laboratory can be conducted. Sites for these cross-checks are determined by the project leader. Samples from these sites are taken in duplo and analysed by both laboratories. The results from both laboratories will be presented and possible differences will be discussed.

Appendix A Sample protocol

This section provides technical guidance for step 2.1 (Preliminary assessemt) for the field staff in order to ensure quality of sampling, ensure uniformity and to allow for effective assessment of fieldwork quality.

For a more comphrehensive description of techniques used for site investigation (most relevant for Task 2.2, Preliminary site investigation, and Task 5.1, Detailed site investigation) references is made to The Guidance Document of the Development of Methodologies for NPRPS Guidance document Volume III-2.2-ii. This Guidance document provides a first overview of techniques, which are widely used e.g. Screening techniques, Sampling collection techniques. For more detailed information on sample collection, extraction and testing site investigation tools the user may refer to more detailed data such as:

› Field Sampling and Analysis Technologies Matrix and Reference Guide, Prepared by the Naval Facilities Engineering Command and the U.S. Environmental Protection Agency: http://www.frtr.gov/site/toc.html

› Dutch directive on restoration and management of soil, groundwater and sediment, provides information on 130 techniques for investigation: http://www.bodemrichtlijn.nl/Tools/bodemonderzoekstechnieken/applicatiezoeken-naar-onderzoekstechnieken (English translation is provided on this internet page).

0. Sampling strategy

Soil sampling:

probable distribution of contamination	Examples	sampling strategy
Spot	spills, confined contaminated areas, storage tanks e.g.	take 1 to 2 topsoil samples from the most visible contaminated areas
Diffuse	embankments, larger areas covered with contaminated materials, like dumpsites storage areas e.g.	make a composite sample from 3 to 5 parts from the topsoil with comparable characteristics.

Make sure that the soil samples are taken from 1) areas with highest concentration (to compare with SSLs and Response Levels) and 2) areas with the most sensitive landuse.

Groundwater sampling:

Take 1 to 2 groundwater samples from tube wells in anticipated downstream direction on site and/or in the direct vicinity of the site. Select the tube wells with the most sensitive use, used for drinking water purpose, used by a school, e.g.

Surface water sampling:

If it is clear that the source of contamination is caused by surface water based on unnatural colours, smell and/or visible contamination like a floating layer, a sample of the surface water is taken.

1. Drilling

- Use an auger or shovel depending on soil type;
- Use HDPE or PE foil to lay down soil;
- Make a picture/drawing of the position of the drilling and its surrounding and make a picture/drawing of the soil profile;
- Restore all boreholes and surface level with soil after sampling;
- Clean the drilling equipment with water;
- Mark the position of the drilling on the map and record the position with GPS.

2. Soil profile description

A bore log is recorded on a bore log form. The following data (where applicable) must be reported in such a log in the proper place:

- Project number;
- Project title;
- Name of driller;
- Date of execution;
- Number of sampling points;
- Number of samples taken and sampling sections with depth;
- Groundwater level (in meters in relation to ground level);
- Depths of the bottom of the various soil layers;
- Texture of the various soil layers;
- Details on the various soil layers, including the estimated quantities;
- Odours given off by the various soil layers;
- Colours of the various soil layers. The colour can be determined either individually or using Munsell Soil Colour Charts (http://munsell.com/color-products/color-communications-products/environmental-color-communication/munsell-soil-color-charts/), which can be considered international standard
- Boring system used.

3. Soil sampling

- Wear gloves during sampling to prevent contaminated soil from coming into contact with your hands;

- Sampling must occur per type of soil (based on texture and organic matter content) and per degree of contamination (based on sensory observations), and normally at most 50 cm of excavated material may be collected per sampling jar.

Instructions for filling a sampling jar:

- Collect the least "smeared" soil by using a spoon or the cap of the sampling jar. Scrape the soil to be sampled into the sampling jar using the inside (be-

cause of the ink) of the sampling jar's cap;
The cap should not be used for filling the jar, as soil and gravel will make it difficult to close the cap. Use of a trowel or spatula should be preferred.

- For technical reasons, clay and loam usually need to be sampled by breaking off pieces of clay by hand (wear clean latex gloves!) or by cutting with a clean spatula or spoon;

- Make sure that the mass of soil in a sampling jar is representative of the section from which it has been taken by ensuring that the locations of the subsamples are proportionally distributed over that section;

- Each sampling jar must be filled to the limit. Clean the screw thread of the jar and of the cap and screw the cap on tightly to lower the chance of contaminants evaporating. The soil in the jar should be compressed to the maximum to reduce pore space and headspace, to reduce loss of volatile substances.

- Immediately store the samples at a low temperature (<5 degrees celcius). Storage of samples at low temperatures should be extended with the advice that samples should reach the laboratory asap, and that laboratories offer information about maximum storage time before analysis will be affected.

4. Groundwater sampling

- Measure groundwater level in relation to the top of the well and surface level if possible;

- Purging a monitoring well before sampling is important and enhances the quality and representativeness of a groundwater sample. Rinse until at least 3 x the volume of the well's waterbearing part has been removed.

  Air bubbles in the water samples should be avoided, as volatiles may escape from the water and the air oxygen may cause degradation or oxidation of contaminants. Bottles and vials should be filled above maximum forming a meniscus, screw on the cap carefully, turn the bottle upside-down to check for air. If an air bubble is visible, open again, use the cap to fill the bottle up to the meniscus, etc.

- Measure pH and temperature of the groundwater;

- Code the (preserved) sampling bottle (see coding of samples);

- If analysis on heavy metals is required, the sampled groundwater needs to be filtered through a 0.45 µm filter in the field;

- To minimize turbulence during the sampling, run the pump at low capacity, tilt the bottle and lead the water along the bottle's wall;

› The sample volume, packaging and preservation method must be in agreement with the analytical requirements;

› Immediately store the samples at a low temperature (<5 degrees celcius). Storage of samples at low temperatures should be extended with the advice that samples should reach the laboratory asap, and that laboratories offer information about maximum storage time before analysis will be affected. Also, it should be kept in mind that sampling is the biggest source of errors in environmental assessments, not the precision of the machines in the lab.

The following should be reported:

› Well number (see coding of samples);
› Groundwater level in relation to the well's top and surface level;
› The well's depth in relation to its top and surface level;
› pH and temperature
› Purged volume;
› Date of execution;
› Name of sampler.

5. Labelling of samples

In the field, the following is marked on the jar or bottle with an indelible felt-tip pen:

› Site identification number;
› Sample code (see coding of samples);
› Sample or well depth;
› Date of sampling.

6. Coding of drillings and samples

Following coding of drillings and samples will be used:

type of drilling and sampling activity	**code**
shallow drilling and soil sampling	S1, S2, etc.
(deep)well and groundwater sampling	DW1, DW2 etc.
sediment sampling	SS1, SS2 etc.
surface water sampling	SW1, SW2 etc.
composite sample soil	CS1, CS2 etc.
composite sample sediment	CSS1, CSS2 etc.

For example, two soil samples and one groundwater sample taken at a site in the State Andhra Pradesh with ID number AP-500-1 will get the following codes:
› AP-500-1 S1
› AP-500-1 S2
› AP-500-1 DW1

And one soil sample and one groundwater sample taken at a site in the State Bihar with ID number BR-851-1 will get the following codes:
› BR-851-1 S1
› BR-851-1 DW1

7. Amount of samples

It has to be stated that sampling in general only include limited samples of soil and water samples (typically groundwater and surface water). Normally, no deeper soil sampling will be conducted (samples will be taken with shovel or hand auger). Groundwater samples will normally be taken from existing borings on-site and/or off site (if any). For certain type of sites (e.g. spill from underground storage tanks), it can be necessary to use machine driven borings equipment to reach the necessary depth for taking out soil samples. The requested number of samples will depend of the site specific conditions. 1-3 soil samples from source areas and 1-2 water samples from existing wells or surface water is the minimum number of samples. In case for example different sources are present at one site, more samples can be taken. It has to be stated that the objective of the sampling is not to have complete understanding of sources or the spreading of the contamination. This more detailed sampling will be performed in Step 2.2 (Preliminary investigation) and in Step 5 (Remediation Investigation).

8. Storage and shipment of soil samples

Sampling jars and bottles filled with soil and groundwater must be stored at a location which is as cool as possible (approximately 2 - 4 degrees Celsius) and protected from sunlight during the remainder of the field work. After the field work, the soil samples must be transported to the laboratory as soon as possible.

9. Field logbook

A field logbook is intended to provide data and observations required for participants to reconstruct events that occurred during the field work.

The field logbook should contain the following information per site:

- Personal data on team members, site contact person(s);
- Times of arrival and departure of team members;
- Summary of all discussions and agreements made with team members and site owners/stakeholders;
- Explanations of all deviations from the original field sampling plan;
- Descriptions of problems which occurred at the site, noting when and how it occurred, and how it is being addressed;
- Personal protective measures taken;
- Drilling and sampling information: identification number of boreholes, borehole logs, samples etc.;
- Groundwater purging: amount of groundwater purged and yield of well, pH and EC measurement;
- Monitoring well information: identification number, depth of well, samples etc.

Appendix B Estimation of people at risk

Estimated Population at Risk (methodology according to Blacksmith Institute Toxic Site Identification Program – Investigator Handbook):

Population at risk - one of the most important input parameter to the prioritization of probably contaminated sites and should be calculated for all sites.

This is your estimate of the number of people that could be exposed to this pollution at a level (dose) that could impair their health. The ISS should identify both the likely number of people impacted and the total number that might be impacted in a worst case. For example the likely population at risk could be:

- the local residents in a neighbourhood with contaminated soil; or
- the number of school children and residents in the immediate vicinity of a lead smelter or other toxic air pollution source; or
- the population drinking contaminated groundwater.

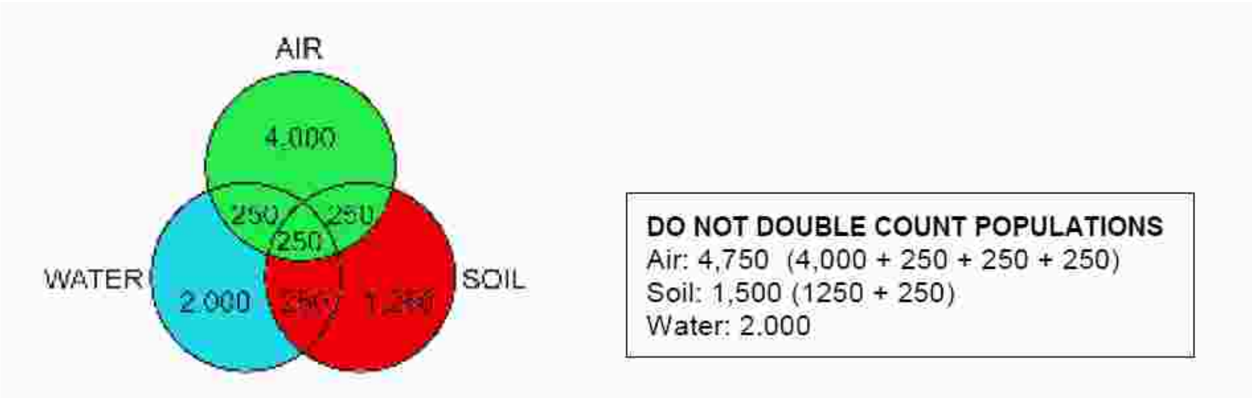
A worst case impacted population at risk estimate would include a larger number than the number of people who could be exposed to the toxic pollution. Examples might be:

- the total population in a 1 kilometre radius of a lead smelter or other air pollution source; or
- the entire population of a town in which a large industrial estate is located; or
- the entire population of an area relying on a contaminated aquifer or surface water source (as opposed to just the population relying on wells sampled and found to be contaminated).

Good professional judgment should be used in developing population estimates, using available information from maps, government sources (regarding such things as town population and water sources) and your own observations. An approximate estimate of the Population At Risk is OK. You may round off to the nearest thousand. For example, if 750 people are exposed, then round up to 1,000. Keep in mind that it is not uncommon to have exposed populations in the 10’s of thousands.

Please note that contaminant migration and pathways define the population at risk. Once a pollutant has been shown to be above the standard, consider the aerial extent of the contamination and how it gets inside of humans. Are people absorbing it by drinking it, breathing the air, inhaling or accidentally ingesting dust, eating food? This pathway will help you to ask the right questions and determine the population at risk. There are often multiple pathways at a given site. Soil that contains lead can contaminate barefoot children through dermal contact or ingestion, though it can also be inhaled as dust by local community members. Similarly, dust containing arsenic can be inhaled or ingested, and can also migrate to drinking water supplies and be ingested. Multiple pathways must be considered when reviewing a site. The total Population At Risk is therefore the total number of people when considering all pathways at a site.

Consider the chart below:



Note that a single person may be put at risk by more than one pathway, though they can only be counted once in the total Population At Risk. The box above illustrates that while multiple pathways can impact the same group, each group can only be counted once.

Finally, remember that you are only expected to estimate Population At Risk within a reasonable range. Make an educated guess by using your screening information and tools such as local maps or census data, or Google Earth to estimate the number of nearby housing units.

Appendix C Universal source categorisation (UBI) and tracers

UBI code

After more than 20 years of soil investigation and remediation in the Netherlands, a legislative change resulted in a more risk based remediation approach of contaminated sites. In line with these legislative changes, it was also concluded that the national remediation program should end within approximately 20 years. Given these changes there was a need for a national inventory to classify and prioritise contaminated sites and to assess the volume of the national remediation program. For this the UBI (Uniforme Bedrijfs Informatie) approach was developed.

The UBI approach consists of a UBI-code and a UBI-class. A long list of historical activities has been identified for the Dutch situation. The different identified activities have then been assigned a unique UBI-code. For all the unique activities, representative tracer components have been identified which are typically used in regard to the identified activity. The UBI-code can thus be used as a preliminary method to identify tracer components, which are regularly used for the identified activity. The tracer components can be seen as components of concern (CoC).

If there is existing information about contaminants from previous investigations, this information should be used to select tracers to be analysed. It has to be stated that not all the listed tracers necessarily has to be analysed at a site, but the list can be used as a starting point for the assessing analysis program at a specific site.

The UBI-codes has been used as a preliminary approach for assessing chemical tracers for various industry types. In an Indian context the HWR Schedule I "List of processes generating hazardous wastes" could probably be used, although it will require some effort to point out chemical tracers for the various processes (in total 36 overall processes). It is our recommendation that a similar approach for assessing tracer compounds should be developed based on the above HWR Schedule I. Until this is developed,we recommend using the below list of UBI-tracer.

Source Industry	UBI-code	UBI-description	UBI -tracers
Aluminium Smelting	2742	aluminium plant	copper (Cu)
			lead (Pb)
			Trichloroethane
			Trichloroethene
			Vinylchloride
			Xylene
			zinc (Zn)
Chemical Manufacturing	24	chemical industry	black box
Chemical works: Fertiliser manufacturing works	2415	fertilizer industry	Asbestos
			cadmium (Cd)
			Calciumfluoride
			chromium (Cr)
			copper (Cu)
			zinc (Zn)
Chemical works: Inorganic chemicals manufacturing works	2413	inorganic chemical raw material factory	Asbestos
			black box

Source Industry	UBI-code	UBI-description	UBI -tracers
Chemical works: Organic chemical manufacturing works	24142	organic chemical raw material factory	Asbestos
			black box
Chemical works: Pesticides manufacturing works	2420	agrochemical industry	1,3-dichloorpropeen
			3,4-dichlooralinine
			Asbestos
			DDT
			Dimethoaat
			Endosulfan
			Lindaan
			Mcpa
			Methylbromide
			Parathion
			Simazin
			Zineb
Chemical works: Pharmaceutical manufacturing works	2442	pharmaceutical products factory	Asbestos
			Chloroform
			Dichloromethane
			Toluene
			Trichloroethene
			Vinylchloride
Dye Industry	2412	paint and dye industry	Asbestos
			Benzene
			Benzidine
			chromium (Cr)
			Phenol
			lead (Pb)
			Toluene
			trichloroethene
			vinylchloride
			zinc (Zn)
Electrical & electronic equipment and clothing manufacturing works	2971	electrical household appliance factory	asbestos
			copper (Cu)
			lead (Pb)
			o-cresol
			tin (Sn)
			trichloroethane
			trichloroethene
			vinylchloride
	18	clothing industry	fluoranthene
			xylene
General manufacturing			black box
Heavy Industry (casting, rolling, stamping)	2710	pig iron and steel industry	cyanide
			fluoranthene
			copper (Cu)
			lead (Pb)
			trichloroethane
			zinc (Zn)
Heavy Industry (casting, rolling, stamping) i.e.	2710	pig iron and steel industry	cyanide
			fluoranthene
			copper (Cu)
			lead (Pb)
			trichloroethane
			zinc (Zn)
Industrial dumpsite	900038	dumpsite industrial waste on land	fill
			black box
Industrial/Municipal dumpsite	900038	dumpsite industrial waste on land	fill
			black box
	900052	dumpsite domestic waste	fill

Source Industry	UBI-code	UBI-description	UBI -tracers
		on land	
Lead smelting (with ingot production)	275407	plumbing factory	arsenic (As)
			asbestos
			cadmium (Cd)
			fluoranthene
			copper (Cu)
			lead (Pb)
			tin (Sn)
			zinc (Zn)
Lead-Battery Recycling	314002	accu recycling factory	antimony (Sb)
			asbestos
			cadmium (Cd)
			lead (Pb)
			nickel (Ni)
			pcb's
			Trichloroethane
Metal manufacturing: Iron and steelworks	27102	steel factory	Cyanide
			Fluoranthene
			copper (Cu)
			lead (Pb)
			Trichloroethane
			zinc (Zn)
Mining and Ore processing	631111	ore and mineral processing industry	arsenic (As)
			Asbestos
			copper (Cu)
			nickel (Ni)
			zinc (Zn)
Mixed (electronic, equipment, clothing industries)	2971	electrical household appliance factory	Asbestos
			copper (Cu)
			lead (Pb)
			o-cresol
			tin (Sn)
			Trichloroethane
			Trichloroethene
			Vinylchloride
	18	clothing industry	Fluoranthene
			Xylene
			black box
Oil refineries & bulk storage of crude oil and petroleum products	232	oil processing industry	Anthracene
			Asbestos
			Benzene
			benzo(a)pyrene
			Fluoranthene
			copper (Cu)
			n-decane
			n-octane
			o-cresol
			Toluene
			Xylene
			zinc (Zn)
Others			black box
Power Plant (coal or oil) & Tanneries	400021	power plant	arsenic (As)
			Asbestos
			benzo(a)pyrene
			Fluoranthene
			copper (Cu)

Source Industry	UBI-code	UBI-description	UBI -tracers
			lead (Pb)
			n-octane
			nickel (Ni)
			PCB's
			Xylene
			zinc (Zn)
Product Manufacturing (electronics, equipment, clothing)	2971	electrical household appliance factory	asbestos
			copper (Cu)
			lead (Pb)
			o-cresol
			tin (Sn)
			trichloroethane
			trichloroethene
			vinylchloride
	18	clothing industry	fluoranthene
			xylene
			black box
Pulp and paper manufacturing works	211	paper, pulp and cardboard industry	barium (Ba)
			dichloorbenzene
			pentachloorphenol
			trichloroethane
			trichloormethane
			zinc (Zn)
Tannery industry	1910	leather industry	3,4,5-trihydroxybenzoic acid
			arsenic (As)
			chromium (Cr)
			phenol
Vitamin C-Sorbitol manufacturing unit	2442	pharmaceutical products factory	asbestos
			chloroform
			dichloromethane
			toluene
			trichloroethene
			vinylchloride
No information obtained			black box
black box - no specific CoC can be determined, wide range analyses / screening is needed			

Appendix D Typology at contaminated sites

The typology of contaminated sites offers important elements when developing a site assessment strategy and remediation options in a manageable way. These elements are activities leading to contamination, geometry and type of contamination. Combined with site specific information on chemical substances and soil characteristics, this typology is useful to get an insight in realistic remediation options to facilitate the process of remediation option appraisal. The typology is described in The Guidance Document of the Development of Methodologies for NPRPS, Volume I and is attached in this Appendix D.

Annex to the Glossary

Explanation of Typology of contaminated sites

1 Introduction

The typology of contaminated sites offers important elements when developing a site assessment strategy and remediation options in a manageable way. These elements are activities leading to contamination, geometry and type of contamination. Combined with site specific information on chemical substances and soil characteristics this typology is useful to get insight in realistic remediation options to facilitate the process of remediation option appraisal.

2 Typology

Table T1 presents an overview of the typology, by showing all activities leading to contaminated soil and types of spreading. These activities are regardless of the party causing the contamination. E.g. liquid phase contaminations are not necessary focused only to industrial activities. On the other hand it is expected that most of this type of contaminations can be found in industrial areas. The following main types of contaminated sites are distinguished using this approach:

Source related:
- Type S1: Land bound solid phase contamination;
- Type S2: Water bound sediments solid phase contamination;
- Type L: Land bound liquid phase contamination. The source of this type of contaminations is connected to human activities or infrastructure.

Pathway related:
- Type P1: NAPL contaminants in soil (Non Aqueous Phase Liquids);
- Type P2: Groundwater contaminations.

Note 1: Although elements in the typology are based on the ‘source-pathway-receptor’ approach, it is not primary ‘receptor’ (risk) based. The typology is not based on risks (risks to human health, ecological risks, spreading or vaporizing). This is because site assessment and soil remediation options appraisal, for which this typology is developed, is not limited to the assessment of unacceptable risks, but needs to give insight in a contaminated site as a whole.

Note 2: depending on a specific situation:
- a combination of these types may be found on one site. Example: a land bound storage of Chromium containing hazardous waste (type S1), leaching Chromium to groundwater and leading to a contaminated groundwater plume (type P2). This combination of types on one single site could result in multiple site assessment strategies and multiple remedial options, each assessing the different types of contaminants (both the site assessment and remediation approach can be combined for practical reasons);
- multiple sites can form a cluster of contaminated sites of a specific type or combination of types. A combination of sites of a specific type in a single cluster or a combination of types on a single site can be recognized. These situations could be indicated as a “cluster-site” with a wide variety of scales. In general, the applicability of remediation techniques will not depend on this setting, but correct balancing of remediation techniques per type of site in a cluster will lead stakeholders to the best applicable remediation option.

Note 3: Both in type L as in type P1 liquid phase contaminants are involved. Type P1 is distinguished from type L by the specific type of contaminant, Non-Aqueous Phase Liquids (NAPL’s), which have a characteristic spreading pattern on or in the groundwater aquifer. This characteristic leads to different site assessment strategies, spreading mechanisms, risk profiles and remediation approaches for type P1 sites, as compared to type L sites. A type L site may, due to further spreading of the contaminant plume, develop over time into a type P1 site.

The main types listed above are based on normative characteristics, which play a role in determining the basics for remediation options. Side characteristics may do so as well, but their influence will in certain cases be restricted to the finer points (mostly technical details) in the selection of remediation options or to the planning or implementation of remediation actions. Thus subtypes come into perspective when remediation option appraisal is going into the second step of option appraisal, the detailed engineering phase. In this detailed engineering phase aspects have to be included related to contaminant specific specifications of remediation techniques, assessment of specific social aspects of the remediation actions or site use specific technical requirements.
Case example. The first step of a site specific remediation option appraisal, based on normative characteristics only, has shown that the remediation should be implemented within a period of less than two months and should result in a removal of all contaminants. In this case only then the site will meet the specific needs for planned reconstruction works. At this point it is already clear that only excavating techniques will be applicable, rendering the assessment of in situ techniques obsolete. This saves gathering and analysing detailed information on the performance of these techniques (e.g. contaminant related performance of in situ techniques) as this will not meet any purpose.

Subtypes can be distinguished based on the following secondary criteria:

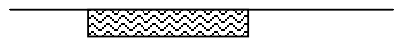
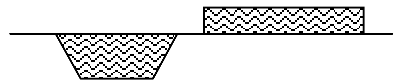
- **Type S1 and L** related subtypes are defined, based on the activity causing the contamination. HW-Schedule I (listing processes generating hazardous wastes) may help to focus on possible activities.
  In Table T1 these subtypes are coded ‘a’ through ‘f’ (type S) and ‘a’ through ‘d´ (type L).
  These subtypes are distinguished to support the site assessment.

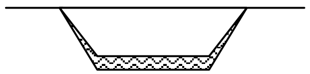
- **Type P1** related subtypes are defined, based on the bulk density of a NAPL (non aqueous phase liquids, dense and light).
  In Table T1 these subtypes are coded ‘a’ and ‘b’ (type P1).
  These subtypes are distinguished to support the site assessment.

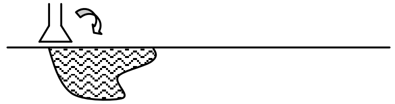
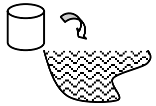
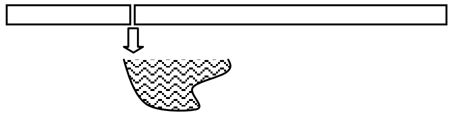
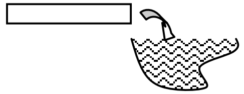
The typology is aimed to support the remediation options appraisal. Some examples to illustrate this point. A site assessment plan for a S1-f type contaminated site (deposition by flooding or washing) will focus on the boundaries of the flooded areas of a river system, easily recognizable on maps or areal pictures. Once the pattern of flooding is known an extensive sampling plan can be carried out to validate the flooding pattern and to validate the hypothesis on the spreading of the contamination with field data. By contrast, a site assessment plan for a S1-c type of contaminated site (storage of contaminated material) will focus on a relatively small area where human activities such as incineration have taken place.

The total volume of the removal of contaminated material, which accounts for the major part of remediation costs, will be smaller for a S1-e type of contaminated site (atmospheric deposition) than for a S1-a type (soil mixed with contaminated material). Therefore, it is more likely that the best applicable remediation option on a S1-e type site will be a complete removal of all contaminants, where for a S1-a type site a capping option is more likely to come into perspective.

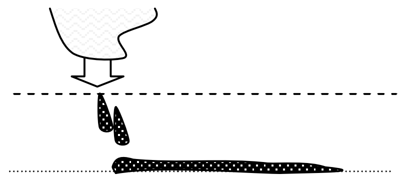
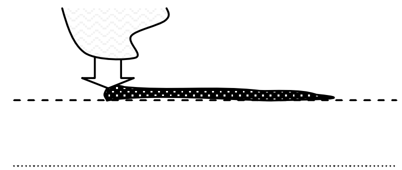
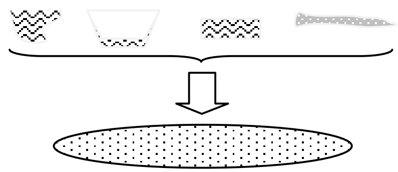
Table T1 Typology

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
S-1	Solid phase contamination (land bound site)		
S1-a *	Mixing the soil with contaminated material or materials containing contamination, not including agricultural activities.	Well defined body below surface level defined by boundaries of soil where soil is mixed with contaminants.	
S1-b **	Embankment, filling of pits or depressions, filling of surface waters with contaminated material or materials containing contamination.	Well defined body of non-mixed contaminants . E.g. storage of tailings.	
S1-c **	(Bulk) storage of contaminated material or materials containing contamination. (Industrial) activities in which contaminated solids are used. 'Leftovers' of incineration and burning of material.	Irregular shaped layer of contaminated material, recognizable as such. The shape of the contaminated site is related to the activity leading to the contamination	
S1-d *	Adding material containing contamination through agricultural activities (e.g. pesticides, fertilizers or additives to animal feed).	Agricultural site bound contaminations found up to a depth to which the soil is treated by ploughs and other agricultural tools.	
S1-e *	Atmospheric deposition (roads, railway, industries) of emissions or windblown dust.	Thin layered contaminations found over large areas with the highest concentrations close to the source following the prevailing wind direction.	
S1-f *	Deposition by flooding or washing.	Contaminations found in areas flooded by water systems or in downstream areas of flooding areas. The shape of the contaminated site is	

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
		determined by the flooding of flow of a water system.	
S-2	Solid phase contaminations (water bound site)		
S-2 **	Contaminated open water sediments.	Solid phase contaminants sedimented from surface water. The shape of the contaminates site corresponds to the shape of the water system itself. Contaminants may be bound to clay or organic compounds of sediments.	

Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
L-1	Liquid phase contaminations		
L1-a *	(Business) activities involving fluids e.g. solvents, lubricants, paint, etc.	Liquid contamination in soil situated near a potential source of the contamination.	
L1-b *	Storage of liquids that contain contaminations in tanks or barrels (either storage on surface or subsurface).	Liquid contamination in soil situated at any place at a liquids storage site.	
L1-c *	Transfer and transport of fluids through linear infrastructure. Weak points are couplings, pressure regulators, valves, breakpoints and the passage through foundations / buildings.	Liquid contamination in soil situated at any place along a transport piping system or drains.	
L1-d	Spills or leaks of liquids. (either on surface or in rivers/lakes) *Note. Possibly leading to type S2 or P2.*	Liquid contamination in soil situated at the end of a transport piping or drain system.	

*) caused by multiple sources or situation where source cannot be attributed.

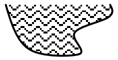
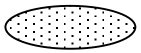
Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
P-1	Liquid phase related		
P1-a	Dense Non-Aqueous Phase Liquid (DNAPL [a])) in permeable soil. (bulk density > water)	Spreading of liquids due to gravity flow resulting in a characteristic spreading pattern. The DNAPL's laying of the botom of an aquiffer can result in a 'secondary source' of spreading of type P-2)	
P1-b	Light Non-Aqueous Phase Liquid (LNAPL [b])) in permeable soil. (bulk density < water)	Spreading of liquids in a characteristic spreading pattern of floating layers. The LNAPL's laying at the top of a water table can result in a 'secondary source' of spreading of type P-2)	
P-2	Leached or dissolved contaminants		
P-2	Groundwater contamination	Due to spreading of leachate or mobile dissolved contaminants in a permeable soil	

a) *A dense non-aqueous phase liquid or DNAPL is a liquid that is both denser than water and is immiscible in or does not dissolve in water. The term DNAPL is used primarily by environmental engineers and hydro geologists to describe contaminants in groundwater, surface water and sediments. DNAPLs tend to sink below the water table when spilled in significant quantities and only stop when they reach impermeable bedrock. Their penetration into an aquifer makes them difficult to locate and remediate. Examples of materials that are DNAPLs when spilled include chlorinated solvents or creosote.*

b) *Light Non-Aqueous Phase Liquid (LNAPL) is a groundwater contaminant that is not soluble and has a lower bulk density than water, which is the opposite of DNAPL. Once LNAPL infiltrates through the soil, it will stop at the water table. The effort to locate and remove*

LNAPL is relatively cheaper and easier than DNAPL because LNAPL will float on top of the water in the underground water table. Examples of LNAPLs are gasoline and other hydrocarbons.

Table T2 Key to icons in table T1

Icon	Key
	Solid waste or solid waste mixed with soil (all solid phase). Varying in shape, thickness and extent, depending on local conditions.
- - - - - - - - - - - - - - -	Groundwater table Base of aquifer / top of impermeable layer.
	Liquid waste. Pure or mixed with soil.
	Leaching / spreading of contaminants to soil / groundwater. Depending on permeability of the soil.
	Contaminated groundwater plume. Depending on permeability of the soil.
	DNALP or LNAPL.
	Spill / leakage.
	Not soil related human activity / construction e.g. industrial process, storage, bulk transfer.

Appendix E SIP Form

Witteveen + Bos

Tauw

COWI

MINISTRY OF ENVIRONMENT AND FORESTS

SITE INSPECTION FORM - TEMPLATE

ADDRESS COWI A/S
Parallelvej 2
2800 Kongens Lyngby
Denmark

TEL +45 56 40 00 00
FAX +45 56 40 99 99
WWW cowi.com

SITE ID:
SITE NAME:
STATE:
STATUS:

CONTENTS

PROJECT NO. P-46909-D-15
DOCUMENT NO. 00
VERSION 04
DATE OF ISSUE March 21, 2013, rev. July 8 2014, November 15 2014, 23 January 2015 (Final version)
PREPARED B.v.d.Enden
CHECKED Torben Jørgensen
APPROVED Søren Viegand

1 Existing and general information (to be filled in before Site Inspection)

Data sheet no. #		
1.	**General Site Information**	
1.0	State Name	
1.1	ID number (State-district-xx)	
1.2	Site Name	
1.3	Address (Street, Street number, postal code)	
1.4	GPS coordinates /and elevation (x, y coordinates of the corners of perimeter) - (The coordinates should be written in Geographic latitude and longitude (North and East) for use in India throughout the report) (add more points if required)	Location of coordinates is shown on map in section 6
1.4.1/ 1.4.2	1	X:
		Y:
	2	X:
		Y:
	3	X:
		Y:
	4	X:
		Y:
1.4.3	Altitude (m above sea level)	
1.6.1	Who is the current owner (name and address)	
1.6.2	Who was the previous owner (name and address)	
1.6.3	What is the current status of contact with owner	
		1=Owner known and in communication with regulator; 2=Owner known but not available/communicating; 3=Owner not known
	Site Access (yes/no, any restrictions?). Will the Consultant have access to the site for field investigations	
	Contact person	
	Phone number	
	What are the available dates / hours to visit the site?	
	Are safety measures required by the owner of the site? If so, which safety measures? Are there any known dangers which a visitor should be aware of like unstable buildings and structures, toxic liquids, holes etc.).	
	Is there a permission to visit / investigate the whole site?	
1.10 + 1.11	**Historical review and overall Site description** Describe historical information about the site (industrial activities, including maps of features of these sites e.g., production area, storage area, underground storage tanks, information on reported spills/dumping etc. Give an overall description of the site including a clear description	

Data sheet no. #		
	of the type of site e.g.: i) is the site a point site with former or ongoing industrial activities on the site; ii) is the site an industrial area (with cluster of industries = Area Site) with no clear source of contamination); iii) is the site an area (e.g. waste land/water body/habitation area) where contamination has been spread via effluent or dumping of waste from an industry (or number of industries) which is placed outside the site boundary. Specify if there are any uncertainties with the Site Definition.	
1.16	Extend of data available (if any).	 A=Almost no information; B=Desk top study performed but no primary data; C=Site investigations performed an primary data available; D=Ongoing remediation; E=Other (specify).
1.17	Previous or ongoing remediation activities (if any)	
2.	**Source of contamination and waste characteristics**	
2.7.1	Give a brief summary of previous investigations performed at the site and in the vicinity (if any). Describe results of soil, air, groundwater and surface water on/off the site (if any). Analysis results should be included. For soil analysis max concentrations in should be reported if possible distinguish between top soil and deeper soil contamination. Depth must always be specified. For groundwater data depth of sample should be reported.	
2.7.2	Compare primary data with SSLs and Response Levels. Calculate the over standard ratio of the maximum concentration level compared to the screening value.	
3.	**Groundwater use and characteristics**	
3.1	Geology at the site. Give an overall description.	 Broad description of the typical stratigraphical sequences from topsoil to deepest aquifer. Based on earlier studies and / or general knowledge.
3.2.1	Hydrogeology - Overall description.	 Describe the depth of aquifers which is relevant for migration of contamination and drinking water/irrigation. The aquifers can be secondary/shallow aquifers and deeper aquifers (primary aquifers). Also, describe soil type of aquifers (sand, clay, bedrock, other) based on earlier studies and / or general knowledge.

Data sheet no. #		
3.2.2	Hydrogeology - Groundwater flow direction	Describe direction for each aquifer(if any information).
10.	**Overall Location and site description**	

#: refer to category in Data Sheet

2 Overall assessment of data and data gaps (assessed before Site Inspection based on desktop study)

Item	
Assessment of available data (e.g. analytical results). Can existing data be used to assess present contamination at the site?	
What are the Chemicals of Concern (CoCs)?	
What are the data gaps? (Description of site, location of site, etc.)	
Give an initial assessment of the samples to be taken (soil, groundwater, surface water, other?)	
What are the focus points during the Site inspection?	
Identify important stakeholders who should participate in the Site Inspection	

3 On site Reconnaissance

Date and time of site visit	...
Site investigation conducted by	... .
Spoken with	... ...
Weather conditions during visit	...

Data sheet no. 1. #	General site information			
1.15	Operational status			
		1 = Active/ongoing; 2 = Closed; 3 = Abandoned; 4 = Other (specify)		
1.5.1	What is the current land use?	...		
1.5.2	What was the previous land use?	...		
1.5.3	What is the future land use (planned)	...		
		1 = Agricultural land; 2 = Waste land; 3 = Water bodies; 4 = Forests; 5 = Habitation settlement (Residential/School/Kindergarten); 6 = Commercial; 7 = Industrial, 8 = Mixed (to be specified for each case) and 9 = Other (to be specified in each case)		
1.7	Name(s) of polluter(s)			
		E.g. Name and address of industry, institution or person who caused the contamination		
1.8	Approximate area of site (m2)	...	m2	
	Built-up area (m2 or percentage of total)	...	%	
	Paved area (m2 or percentage of total)	...	%	
	Non-paved area (m2 or percentage of total)	...	%	

Data sheet no.			
1.9	Topography		
		1 = Water; 2 = Plains; 3 = Mountains; 4 = Hills; 5 = Any other (specify)	
1.10	Type of site		
		1 = "Point"site (single industry/dumpsite); 2 = "Area"site(Industrial area or estate (cluster); 3 = Any other (specify)	
1.12	Industry type (which have caused contamination)	...	
		(select from Basetable 4 of the Data sheet in Annex F)	
1.13	Period of operation/contamination (year)	...	
		Enter period of operation (from – to) Period of contamination (from – to) based on available information	
1.14	Is the site classified before or after the development of HW rules in 1989 (Before / After)		
2.	**Source of contamination and waste characteristics**		
	Are there dump sites present? Describe	yes / no	....
2.1.1	Physically state of waste as deposited		
		1 = Solid, 2 = Sludge, 3 = Powder, 4 = Liquid, 5 = Gas, 6 = unknown, 7 = Any other (specify)	
2.1.2	Origin of the deposit		
		1 = dump, 2 = leakage, 3 = fluviatile deposit (sediment), 4 = areal deposit, 5 = storage, 6 = Effluent (wastewater) 7 = Any other (specify)	
2.1.3	Position in soil/effluent		
		1 = On the surface; 2 = In the soil; 3 = In effluent (wastewater); 4 = Any other (specify)	
2.1.4	Is there visual contamination		
		Describe visual contamination in soil; groundwater; surface water; effluent	
2.1.5	Is there vegetation stress		

Data sheet no.					
		Describe any sign of vegetation stress			
2.1.6	Area of contaminated soil				
		Area of the above source or area of HW deposited			
2.1.7	Volumen of contaminated soil				
		m3 / mt (source in soil or HW deposited)			
2.1.8	Is the source area delineated				
2.1.9	Area of contaminated groundwater				
		If plume is delineated assess the area of the plume (lengt (m), widht (m) area (m2)			
2.2	Type of contamination according to definition from MoeF				
		1 = Effluent; 2 = Air; 3 = Municipal Solid Waste; 4 = Bio-medical Waste; 5 = Hazardous Waste; 6 = Ship Break Waste; 7 = Any other (specify)			
2.3	"Industrial processes" which caused the contamination (According to Base table 5 of the Data sheet in Annex F)	...			
2.4	Type of hazardous waste				
		According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) - select from Basetable 6 of the Data sheet in Annex F			
2.5	Hazardous Waste Constituents				
		According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) - select from Basetable 7 4 of the Data sheet in Annex F			
2.6	What are the COC's? (use UBI Appendix C)	...			
	What potential sources of contamination are present? Quantify as much as possible (area and/or volume) Describe	....			
	Are there storage tanks present at the site? Specify number, sub surface or on	yes / no	... (number)	sub surface / on surface / both	content

Data sheet no.					
	surface, content (chemical) (If specification is available, please add)				
	Is there visible soil contamination present?	yes / no		Take 1 to 2 samples of most contaminated sites	
	What is the level (intensity) of visible soil contamination?	low / medium / high impact		Take photo	
	What is the scale of visible soil contamination? (percentage of total site size)	< 10% / 10 - 50% / >50%			
	Are the buildings visibly contaminated?	yes / no / NA			
	What is the level (intensity) of the building/ infrastructure visible contamination?	low / medium / high impact / NA		Take photo	
	What is the scale of the visible building/ infrastructure contamination? (percentage of total buildings/ infrastructure)	< 10% / 10 - 50% / >50% / NA			
	Are there materials present which might contain asbestos? (corrugated roofing panels				
	Is the present contamination local (hot spot) or diffuse?	hot spot / diffuse / both / none			
3.	**Groundwater use and characteristics**				
3.2.3	Hydrogeology - Depth to water table (m below subsurface, use wet season estimate).				
		Describe the depth to the water table for each aquifer. Based on local knowledge or information from Ground water Authorities or data from Site Inspection			
3.3	Current and future expected use of any aquifer for groundwater use				
		Describe current and future planned use of any aquifer			
3.4	Is the site within a groundwater recharge zone				
		1 = Area with special drinking water interest (i.e. major aquifer/potable water supply)			

Data sheet no.				
		2 = Areas with drinking water interest (aquifer with major aquifer potential) 3 = Areas with borderline drinking water interest (minor aquifer/ non potable water		
	Are there groundwater wells present on site? If so what use (consumption / domestic / industrial), what yield?	yes / no	consumption / domestic / industrial	**Take photo**
	Are there indications of groundwater pollution; e.g. smelling wells. If yes, what is the level (intensity) of groundwater contamination (if noticeable)?	yes / no / NA	...	**Take sample**
4.	**Surface water use and characteristics**			
4.1	Any drainage system (run off system) on site	...		
		General description of (drain, trenches, streams) or streams at the site which can transport the contamination outside the premise to surface water bodies		
4.3	Type of Surface water Body			
		1 = Pond (less than 1 hectare), 2 = Small lake (1-10 hectares), 3 = Large lake (more than 10 hectares), 4 = Small river/stream, 5 = Large river, 6 = Wetland, 7 = Other (specify if possible)		
4.4	Any sensitive use of surface water			
		1 = Drinking Water, 2 = Irrigation, 3 = Use in commercial food production, 4 = Water recreational area (e.g. bathing, marina), 5 = Fishing, 6 = Other (specify if possible)		
4.6	Are there signs of flooding? Describe	yes / no	...	
	If so, what is the water table to the surrounding surface? (m below ssl)	... m - ssl		
	Is there any discharge to the surface water visible? Describe	yes / no / NA	...	**Take photo** **Take sample**
	Is the surface water visibly contaminated? Describe	yes / no / NA	...	**Take photo**

Data sheet no.				
5.	**Soil exposure characteristics**			
5.1.1	Access to the site from local communities			
		1 = Site secured and access controlled 2 = Site not secured but access limited 3 = Open site with regular public activity, 4 = Other (specify)		
5.1.2	Is there inhabitation on the site? If so how many people? How many children?	yes / no	… (number)	… (number)
5.1.3	How many workers are working on site? (Number)	…	Remarks: ..	
5.1.4	Specify other activities if any	…		
	Is there agricultural use at the site (crop growing / keeping of domestic stock)? Describe	yes / no	…	
6.	**Air exposure characteristics**			
6.1	What are the prevailing wind directions?	N / NE / E / SE / S / SW / W / NW / unknown		
	Is there a noticeable (smell) /bad air quality at the site? Dust visible? Describe	yes / no	…	

#: refer to category in Data Sheet

4 Off site Reconnaissance

Data sheet No #				
3.	**Groundwater use and characteristics**			
	Are there groundwater wells present? If so what use (consumption / domestic / industrial).	yes / no	consumption / domestic use / industrial	**Take photo** **Take sample if notice-able pollution is present**
3.5.1	Private wells (distances to nearest well and approximate number of wells within 1 km from the site)	... meters	... (number)	
3.5.2	Public wells (distances to nearest well and number of wells within 1 km from the site)	... meters	... (number)	
4.	**Surface water use and characteristics**			
4.1	Any drainage system (run off system) outside the site	...		
		General description of (drain, trenches, streams) or streams at the site which can transport the contamination outside the premises to surface water bodies		
4.2	Name and distance to nearest surface water body (m)			
4.3	Type of Surface water Body			
		1 = Pond (less than 1 hectare), 2 = Small lake (1-10 hectares), 3 = Large lake (more than 10 hectares), 4 = Small river/stream, 5 = Large river, 6 = Wetland, 7 = Other (specify if possible)		
4.4	Any sensitive use of surface water			
		1 = Drinking Water, 2 = Irrigation, 3 = Use in commercial food production, 4 = Water recreational area (e.g. bathing, marina), 5 = Fishing, 6 = Other (specify if possible)		
	Is there surface water directly next to the site? If so, what type	yes / no	...	
	What distance is the water table to the surrounding surface? (m below ssl)	... m - ssl		
	Is there visible discharge from	yes / no / NA	...	**Take photo**

	the site visible? (Describe)			**Take sample**
	Is the surface water visibly contaminated? (Describe)	yes / no / NA	...	**Take photo and take sample**
4.5	What is the distance to sensitive environments and Wetlands (m)? (Describe)	... meters	...	
5.	**Soil exposure characteristics**			
5.2.1	What is the land use in the vicinity of the site?	1 = Agricultural land; 2 = Waste land; 3 = Water bodies; 4 = Forests; 5 = Habitation settlement (Residential/School/Kindergarten0; 6 = Commercial; 7 = Industrial, 8 = Mixed (to be specified for each case) and 9 = Other (to be specified in each case)		
	North	...		
	East	...		
	South	...		
	West	...		
	Are there crops grown next to the site? (Describe)	yes / no	...	**Take photo**
	Is there domestic stock present next to the site?	yes / no	...	**Take photo**
5.2.2	What is the distance to the nearest habitation? (Describe)	... meters	...	**Take photo**
	Approximate number of people living within 100 meter	... (number)		
5.2.3	Approximate number of people living within 1 km	... (number)		
5.2.4	What is the distance to other sensitive activities e.g. schools, nursery, allotments (m)? (Describe)	... meters	...	
7.	**Socio economic aspects**			
7.1	Describe general socio economic conditions			
		E.g. employment rate, in-come, rate woman/man, rate in age, population density, occupation,		

		alphabetise, religion, value of site/buildings, possibilities of temporary site clearance, social sensibility land user(s),
7.2	Drinking water source	...
		Describe drinking water source (e.g. public water supply based on groundwater) for the population in he vicinity of the site (within 1 km)

#: refer to category in Data Sheet

5 Miscellaneous

1.18	**Complaints**: List any other pending complaints, claims, liabilities, non-compliances, conversations with site personnel or neighbours and other relevant matters related to soil and groundwater pollution aspects
	Data gaps: List major (if any) data gaps or uncertainties which still occur after the conducted Site Inspections (e.g. insufficient information about geology/hydrogeology)
	Emergency response considerations: List observed conditions that may warrant immediate or emergency action (e.g. heavely contaminated groundwater/surface water used for drinking water, unrestricted public access to exposed hazardous substances etc.).

6 SITE map

Requested information on the site map. If necessary more than one maps can be shown in various scaling:

- Site boundary
- Point with GPS coordinates (with same ID as in section 1.4)
- Sampling location for **all** samples
- Land use (at the site and in the vicinity of the site)
- Location of observed "Source areas"
- Location of points of interests e.g. groundwater wells, surface water bodies
- Photos taken (if possible)
- Scale of map (use scaling bar)
- North arrow

7 Sampling

Site ID + number	soil / water	Date for sampling	Targeted or composite	Location (description and GPS coordinates if available)	Parameters analysed	Motivation of sampling *
1.						
2.						
3.						
4.						

*: Motivation (e.g. visible contamination, source area). Must also include information about landuse (only soil) and location of sample (inside/outside the site)

8 Draft Conceptual site model (CSM)

Based on the available information provide a sketch of the site's Conceptual Site Model:

9 Photographic Record

Number	Description	Location

10 Overview of analysis results from sampling

Soil samples (template – to be modified for the specific analysis programme)

Sample ID		xx	xx	xx	Detection Limit	Screening Level (soil)				Response level (soil)
						Agricul-tural	Residential /parkland	Commer-cial	Industrial	
Depth	m bgs									
Date for sampling (day-month-year)										
Arsenic	mg/kg					12	12	12	12	50
Cadmium	mg/kg					1,4	10	22	22	13 (22#)
Chromium (VI)	mg/kg					0,4	0,4	1,4	1,4	50
Chromium – total	mg/kg					64	64	87	87	180
Cyanide	mg/kg					0,9	0,9	8	8	50
Lead	mg/kg					70	140	260	600	530 (600#)
Mercury	mg/kg					6,6	6,6	24	50	36 (50#)
xx	mg/kg					xx	xx	xx	xx	xx

#: If Screening Level for the current land use exceeds the Response level then the Screening level should be used

Bold: Concentration exceeds Screening values for the current land use at the site

<u>Bold and underline</u>: Concentration exceeds Response Level

na: Not analyzed

Groundwater samples (template – to be modified for the specific analysis programme)

Sample ID		xx	xx	xx	Detection Limit	Drinking water standards		
						Indian Standard for Drinking Water ¤	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water
Depth of sample	m bgs							
Depth to water table	m bgs							
Date for sampling (day-month-year)								
Arsenic	mg/l					0,01		
Cadmium	mg/l					0,003		
Chromium (VI)	mg/l					0,05	-	-
Chromium – total	mg/l					-	0,05	0,05
Cyanide	mg/l					0,05		
Lead	mg/l					0,01		
Mercury	mg/l					0,001		
xx	mg/l					xx	xx	xx

¤: (IS: 10500:2012) Maximum acceptable concentration)

Bold: Concentration exceeds Drinking water standards

na: Not analyzed

Surface water samples (template – to be modified for the specific analysis programme)

Sample ID		xx	xx	Detection Limit	Surface water Quality Standards (Screening levels)					
					The Environment (Protection) Rules, 1986 Schedule VI. General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of Aquatic Life	Canadian Water Quality Guidelines for the protection of Agriculture
Date for sampling (day-month-year)					Inland surface water	Public sewers	Land for irregation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
Arsenic	mg/l				0,2	0,2	0,2	0,2	0,005	0,1/0,025
Cadmium	mg/l				2	1	-	2	Equation	0,0051/0,08
Chromium (VI)	mg/l				0,1	2	-	1	0,001	0,008/0,05
Chromium – total	mg/l				2	2	-	2	0,0089	0,0049/0,05
Cyanide	mg/l				0,2	2	0,2	0,2	0,005 (free CN)	-/-
Lead	mg/l				0,1	1	-	2	Equation	0,2/0,1
Mercury	mg/l				0,01	0,01	-	0,01	0,026	-/-
xx	mg/l				xx	xx	xx	xx	xx	xx
xx	mg/l				xx	xx	xx	xx	xx	xx

Bold: Concentration exceeds Surface Water Quality Standards

na: Not analyzed

11 Overall assessment of pathways, exposure, impacts and contamination, site classification

Data sheet No #		
8.	**Pathways, exposure impacts and risk from contamination**	
8.1	Potential/observed pathways for spreading of contaminants at the site	
		1 = Groundwater pathway, 2 = Surface Water pathway, 3 = Soil exposure pathway, 4 = Air pathway 5 = Any other (specify)
8.2	Potential/observed exposure to contaminants	
		1 = Direct human contact, 2 = Ingestion (soil, food) 3 = Groundwater use (Drinking water, Irrigation), 4 = Inhalation of polluted air/dust, 5 = Surface water use (drinking water, bathing, fishing), 6 = Sensitive environments, 7 = Other (specify)
8.3	Describe observed impacts (if any)	
		E.g. observed impacts on humans, animals, flora, fauna
8.4	Estimation of population at risk (see Appendix B) <1000 1.000 – 5.000 5.000 – 10.000 10.000 – 20.000 20.000 – 50.000 50.000 – 100.000 100.000 – 200.000 200.000 – 500.000 >500.000	Specify

Data sheet No #		
9.1/ 9.2/ 9.3	Typology of contaminated site according to standard, see Appendix D (Note that more than one typology can be applicable): **S-1 Soil Phase contamination (land bound site):** (Subdivided into S1 – a; S1 – b; S1 – c; S1 – d; S1 – e; S1 – f) **S-2 (Solid Phase contaminations (water bound site)** **L-1 (Liquid phase contaminations)** (Subdivided into L1 – a; L1 – b; L1 – c; 1 – d) **P-1 Liquid phase related** (Subdivided into P1 – a; P1 – b) **P-2 Groundwater contamination** (Leached or dissolved contaminants) Specify overall typology, and if possible also subdivision of typology	
	Assessment of contamination from Site Inspection (based on analytical results from Site Inspection – see Section 10 and 12) (Specify most critical contaminants, specify if concentrations exceeds SSLs and Response Levels) If lack of data, include results from previous investigations (if any)	Soil: Groundwater: Surface water:
	Conclusion and recommendations: Assess whether or not the site meets the definition of contaminated site. Describe recommendation for the next step in the assessment and remediation process. If the information is to insufficient to draw a conclusion a recommendation for further investigation should be provided.	

#: refer to category in Data Sheet

12 Analytical Test Report

13 Field logbook from sampling

14 References

Appendix F Data sheet - template

Overall Topic	No	Topic		Explanation	Actual description
1. Generel site information	1.0	**State name**			
	1.1	**ID number** *(State-district-xx)*			
	1.2	**Site Name**			
	1.3	**Adress**		*Street, Street number, Postal code, City*	
	1.4.1	**GPS coordinates /and elevation**	Latitude (enter as decimal)	*X, Y and Z coordinates in center of the site)*	
	1.4.2		Longitude (enter as decimal)		
	1.4.3		Altitude (m above selevel)		
	1.5.1	**Land use**	*Current landuse*	*1 = Agriculture land, 2= Waste land, 3 = Water bodies, 4 = Forests, 5. Habitation settlement (Residential/School/Kindergarten), 6 = Commercial, 7 = Industrial, 8 = Mixed (to be specified for each case) and 9 =. Other (to be specified in each case)* ***(Basetable 1)***	
	1.5.3		*Future landuse (planned)*		
	1.6.1	**Owner**	*Current owner (name and adress)*		
	1.6.3		*Contact with owner*	*1 = Owner known and in communication with regulator 2 = Owner known but not available/communicating 3 = Owner not known*	
	1.7	**Name(s) of Polluter(s)**		*E.g. Name and adress of Industry, Institution or person who caused the contamination*	
	1.8	**Approximate area of site** *(m2)*			
	1.9	**Topography**		*1 = Water, 2 = Plains, 3 = Mountains, 4 = Hills, 5 = Any other (specify)*	
	1.10	**Type of Site ("Point" site or "Area" site)**		*1 = "Point" site (Single industrial site/dump site), 2 = "Area" site Industrial area or estate (cluster) 3 = Any other (specify)* ***(Basetable 2)***	
	1.11	**Historical review**		*Describe historical information about the site (Industrial activities, including maps of features of thes site e.g. production area, storage area, underground storage tanks, information about reported spills / dumping, etc.*	
	1.12	**Industry Type (which have caused contamnation)**		*Select from* ***Basetable 4*** *:* *The list is by no means exhaustive and is provided as a guide only. Where one or more of the activities on the list has been undertaken at the site, the site is not necessarily contaminated but there is an increased risk of contamination being present)*	
	1.13	**Period of operation/contaminating**		*Enter beginning year and end year e.g. 1988 - 1995*	
	1.14	**Is the site classified before or after the development of HW rules in 1989**			
	1.15	**Operational status**		*1 = Active/ongoing, 2 = Closed, 3 = Abandoned, 4 = Other*	
	1.16	**Extent of data avaliable**		*A = almost no informations, B = Desk top study performed but no primary data , C = Site investigations performed and primary data avaliable, D = Ongoing Remediation, E = Other (specify)*	
	1.17	**Previous or ongoing remediation activities (if any)**		*Specify activities and references*	
	1.18	**Any complaints regarding the contamination**		*Specify any complaints from e.g. site owner, neighbours, NGOs e.t.c.*	
2. Source of contamination and waste characteristics	2.1.1	**Source characteristic**	Physically state of waste as deposited	*1 = Solid, 2 = Sludge, 3 = Powder, 4 = Liquid, 5 = Gas, 6 = unknown, 7 = Any other (specify)*	
	2.1.2		Origin of the deposit	*1 = dump, 2 = leakage, 3 = fluviatile deposit (sediment), 4 = areal deposit, 5 = storage, 6 = Effluent (wastewater) 7 = Any other (specify)*	
	2.1.3		Position in soil/effluent	*1 = On the surface, 2 = In the soil, 3 = In effluent (wastewater), 4 = Any other (specify)*	
	2.1.4		Is there visual contamination	*Describe visual contamination in soil, groundwater, surface water, effluent*	
	2.1.5		Is there vegatation stress	*Describe any sign of vegatation stress*	
	2.1.6		Area of contaminated soil	*Area of the above source or area of HW deposited*	
	2.1.7		Volumen of contaminated soil	*m3 / mt (source in soil or HW deposited)*	
	2.1.8		Is the source area deliniated?		
	2.1.9		Area of contaminated groundwater	*If plume is deliniated assess the area of the plume (lengt (m), widht (m) area (m ^{2})*	
	2.2	**Type of contamination according to definition from MoeF**		*1 = Effluent, 2 = Air, 3 = Municipal Solid Waste, 4 = Bio-medical Waste, 5 = Hazardous Waste, 6 = Ship Break Waste, 7 = Any other (specify)* ***(Basetable 3)***	
	2.3	**"Industrial processes" which caused the contamination**		*According to schedule 1 - Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008) -* ***select from basetable 5***	
	2.4	**Type of hazardous waste**		*According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) -* ***select from basetable 6***	
2. Source of contamination and waste characteristics	2.5	**Hazardous Waste Constituents**		*According to Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008.) -* ***select from basetable 7***	
	2.6	**Contaminants of concern - CoC - (chemical name(s)**		*Multiple contaminants can be selected). Select from* ***Basetable 8***	
	2.7.1	**Information on previous sampling and analysis (Primary data)**		*Give a brief* ***summary of previous investigations*** *performed at the site and in the vicunity (if any). Describe results in soil, air, groundwater and surfacewater on/off the site (if any). Analysis results should be included.*	
	2.7.2			*Primary data from the site should be compared to Screening Levels (SSLs) and Response Levels (RL) for the most critical chemical constituent (e.g. Cr(VI)*	

Overall Topic	No	Topic		Explanation	Actual description
3 Groundwater use and characteristic	3.1	**Geology at the site**	Overall description	*Broad description of the typical stratigraphical sequences from topsoil to deepest aquifer. Based on earlier studies and / or general knowledge).*	
	3.2.1	**Hydrogeology at the site**	Overall description	*Describe the depht of aquifers which is relevant for migration of contamination and drinking water/irregation. The aquifers can be secondary/shallow aquifers and deeper aquifers (primary aquifers). Also describe soil type of aquifers (sand, clay, bedrock, other) based on earlier studies and / or general knowledge)*	
	3.2.2		Groundwater flow direction	*Describe direction for each aquifer(if any information)*	
	3.2.3		Depth to water table *(m below subsurface).*	*Describe the depht to the water table for each aquifer. Based on local knowledge or information from Ground water Authorities or data from Site Inspection*	
	3.3	**Current and future expected use of any aquifer for groundwater use**		*Describe current and future planned use of any aquifer*	
	3.4	**Is the groundwater used for drinking water**		*1 = Major use of groundwater for drinking water purpose 2 = Moderate use of groundwater for drinking water purpose 3 = No use of groundwater for drinking water purpose 4 = No information Select from* ***Basetable 9***	
	3.5.1	**Drinking water intakes**	Private wells	*Specify distances to nearest well and approximate number of wells within 1 km from the site)*	
	3.5.2		Public Wells	*Specify distances to nearest well and number of wells within 1 km from the site*	
4 Surface water use and characteristics	4.1	**Any drainage system (run off system) on/outside the site**		*Genereal description of (drain, trenches, streams) or streams at the site which can transport the contamination outsite the premice to surface water bodies*	
	4.2	**Name and distance to nearest surface water body (m)**			
	4.3	**Type of Surface water Body**		*1 = Pond (less than 1 hectare), 2 = Small lake (1-10 hectares), 3 = Large lake (more than 10 hectares), 4 = Small river/stream, 5 = Large river, 6 = Wetland, 7 = Other (specify if possible)* ***Select from Basetable 10***	
	4.4	**Any sensitive use of surface water**		*1 = Drinking Water. 2 = Irrigation, 3 = Use in commercial food production, 4 = Water recreational area (e.g. bathing, marina), 5 = Fishing, 6 = Other (specify if posible)* ***Select from Basetable 11***	
		Any sensitive use of surface water within 1 km		*1 = Major use of surface water for sensitive use (use for Drinking Water, Irrigation, Livestock, Commercial food production, Water recreational, Fishing 2 = Moderate use for sensitive purpose 3 = No use for sensitive purpose 4 = No information* ***Pick from Base Table 12***	
	4.5	**Distance to Sensitive Ecological areas (m)**		*E.g. Reserves, wetland*	
	4.6	**Any flooding (yes/no)**		*If any flooding describe frequency and type*	
5 Soil Exposure Characteristics	5.1.1	**Current activities on the site/access**	Access to the site from local communities	*1 = Site secured and access controlled 2 = Site not secured but access limited 3 = Open site with regular public activity, 4 = Other (specify)* ***Select from Basetable 13***	
	5.1.2		*People living on the site (yes/no) (if yes how many people)*		
	5.1.3		*Workers on facility (yes/no) (if yes how many workers at the site)*		
	5.1.4		*Other Activities (if any)*		
	5.2.1	**Activity in the vicinity of the site**?	*Land use in the vicinity of the site*	*Use Land Use categorisation from section 1. Desribe any relevant Industrial faclitities close to the site which also may cause contamination*	
	5.2.2.		*Distance to nearest habitation*	*Distance in m*	
	5.2.3		*Approximate Population within 1 km from the site*		
	5.2.4		*Distance to other sensitive activities (m)*	*E.g. Schools, parkland, agriculture*	
6. Socio economic aspects	6.1	**Describe general socio economic conditions**		*E.g. employment rate, in-come, rate woman/man, rate in age, alphabetisme, religion, value of site/buildings, possibilities of temporary site clearence, social sensibility land user(s)*	

Overall Topic	No	Topic		Explanation	Actual description
7. Pathways, exposure, impacts and risc from contamination	7.1	**Potential/observed pathways for spreading of contamination at the site**		*1 = Groundwater pathway, 2 = Surface Water pathway, 3 = Soil exposure pathway, 4 = Air pathway 5 = Any other (specify)*	
	7.2	**Potential/observed exposure to contaminants**		*1 = Direct human contact, 2 = Ingestion (soil, food) 3 = Groundwater use (Drinking water, Irregation), 4 = Inhalation of polluted air/dust, 5 = Surface water use (drinking water, bathing, fishing), 6 = Sensitive environments, 7 = other (specify)*	
	7.3	**Describe observed impacts (if any)**		*E.g. observed impacts on humans, animals, flora, fauna*	
	7.4	**Total population at risk**		*According to approach describe din Site Inspection Protocol*	
	7.5	**Risc Score from Blacksmit Insitute**		*Enter BI risc score (if included in the BI database)*	
8. Typology	8.1	**Specify typology**	Source Related: **Type S1** and **Type S2**	***Select from note 6.*** ***S1 = Solid phase contamination (land bound site)*** ***S2 = Solid phase contaminations (water bound site)*** ***L = Liquid phase contaminations*** ***P1 = Liquid phase related*** ***P2 = Leached or dissolved contaminants*** *Notice that a site may fit into more than one of these types). If possible specify subtypes as defined in* ***Basetable 14***	
	8.2		Source related: **Type L**		
	8.3		Pathway related: **Type P1** and **Type P2**		
9. Overall description	9.1	**Overall Location and site description**		*For BI sites enter "Abstract" and part of "Location and site description" and/or "abstact". For other sites use summary from existing reports (if any)*	
10. Site Stakeholders and arguments for identifying the site as a probably contaminated site	10.1	**Site Stakeholders**		*(Specify contactperson for this partiular site: e.g. Goverment Environmental Agency, Municipal Authority, NGO/community Agency, Local Health Facility Director, Busines/Coorporate Agency, other Agencies)*	
	10.2	**Name of institution which appointed the site as a "potentially" contaminated"**		*Based on our datacollection in Task 1. Point out Institution(s) (E.g. SPCBs, CPCB, BI, NGOs etc) and contact person*	
	10.3	**Reasons on why the site has been appointed as contaminated /probably contaminated site**			
	10.4	**Comments of SPCBs on the information that thes site is appointed as a probably contaminated site**			
	10.5	**Confirmed by SPCB, CPCB as a probably contaminated sites or SI has been performed by COWI**			
11.Risc	11.1	**Total population at risc**			
	10.6	**Blacksmith Institute Risc score**			
12. References	12.1	**Specify references that describe previous studies performed at the site**		*According to "List of references"*	
	12.2	**Site ID from Blacksmith Institute**		*Enter BI site ID (if included in BI database)*	

Appendix G Draft Screening and Response Levels

The laboratory testing will result in a list of concentration levels for various parameters / substances. These concentration levels have to be compared with the Screening Levels and the Response Levels

A complete List of Screening Levels and Response Levels are shown in Appendix G.

Screening and Response Levels are important to assess the level of contamination.

- Screening Levels are generic concentrations of hazardous substances in soil, sediment, groundwater and surface water, at or below which, potential risks to human health or the environment are not likely to occur and where no further investigation and assessment is needed;
- Response Levels are generic concentrations of hazardous substances in soil and sediments, at or above which, it is very likely there is an imminent threat to human health or the environment. At or above this level some form of response is required to provide an adequate level of safety to protect public health and the environment.

Below, in Appendix Figure 1, the levels are schematically shown indicating the risk they represent and related actions to be taken.

Assessment	Level of risk / Actions to be taken
Hazardous substances exist at levels which may pose existing or imminent risk to human and environment	Unacceptable risk. Further site actions required (investigation, remediation or precautionary measures)
Response Level	
Hazardous substances exist at levels where existing or imminent risk to human and environment is not likely to occur (related to a certain type of land use)	Acceptable risk at current land use. Further investigation needed
Screening Level	
Hazardous substances have not been detected or exist at levels where risk for human and environment are likely to be negligible (related to a certain type of land use)	No risk at current land use. No action at current land use

Appendix Figure 1 Overview of Screening and Response Levels related to risk and actions

Risk levels versus site categorization according to the definition is schematically shown in the figure below. The relation between the definitions of (probably) contaminated sites and the determination of specific Screening/Response Levels can be deducted as follows:

Risk levels and site categorization

Screening Levels

Assessing soil contamination

In India, there are no specific levels for assessing soil contamination. The Canadian CCME Environmental Quality Guidelines will be used as preliminary screening levels in the Indian situation. Four categories of land use are distinguished:

- Agricultural
- Residential/Parkland
- Industrial
- Commercial.

In the table below, we show how to correlate the form of land use from the Canadian Environmental Quality Guidelines with the land uses referred to by the MoEF.

Land use India (Referred to by the MoEF)	Land use in the Canadian Environemtal Quality Guidelines
Agricultural land	Agricultural (including water quality guidelines for agriculture)
Waste land	Industrial
Water bodies	For soil depending on land use
Forests	Residential/Parkland
Habitation settlements	Residential/Parkland
Industrial	Industrial, commercial
Mixed	Choose the most vulnerable land use
Other	Choose the most vulnerable land use

Background levels

In most cases, Screening Levels are well above the natural background levels. The natural background levels of metals and other inorganic chemicals can vary widely, and this should be taken into account when applying the assessment levels. Where it can be demonstrated that *natural* background concentrations are elevated (e.g. heavy metal concentrations in mineralised areas), it would be appropriate to develop less stringent assessment criteria. However, care needs to be taken when establishing the level of the natural background and its natural variation, as the local background level may be influenced by historic mining and/or waste disposal activities. Note that for certain contaminants such as Persistent Organic Pollutants, no background values should be used, as there is no natural background for these substances.

Assessing groundwater contamination

For groundwater, first the intended use (at present or in future) of the groundwater has to be established. Is it to be used for drinking water for humans, for drinking water for animals, for irrigation of crops, or for water in industrial processes? Depending on this, different screening levels can be set up. In India, there are no specific standards for groundwater levels beneath contaminated sites. However, there are specified standards for e.g. drinking water and water used for irrigation.

Groundwater used for drinking water

As Screening Levels for groundwater used for drinking water, the Indian drinking water values considered are as per IS 10500:2012 - (Second Revision) will be used. For contaminants not listed in this document, suggested screening values are taken from Canadian Standards. Where Canadian values are also unavailable, those from WHO are used.

Groundwater used for irrigation

As Screening Levels for groundwater used for irrigation, the current Indian Standard: “The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants” will be used. If there are no Indian standards for a specific compound, the Canadian Water Quality Guidelines for the Protection of Agriculture will be used, see Appendix B.

Assessing surface water contamination

As Screening Levels for assessing surface water impact from contaminated sites discharging waste water to surface water bodies, the Indian standards: “The Environment (Protection) Rules, 1986 Schedule VI, General standards for discharge of environmental pollutants” will be used. The values are divided into 4 categories: 1) Inland/surface 2) Public sewers 3) Land for irrigation and 4) Marine coastal. In general, these values are very high compared to international standards e.g. the Canadian Water Quality Guidelines for the protection of Aquatic Life.

If there are no Indian standards for a specific compound, the Canadian Water Quality Guidelines for the Protection of Aquatic Life will be used as Screening Levels, see Appendix C.

Response Levels

India has no specific levels for assessing soil contamination. Because of that, the Dutch intervention values, which are widely accepted worldwide, is used as response levels. Compared to the Canadian soil screening levels, the Dutch standards are in general a factor 3-10 higher (for sensitive land use e.g. agricultural and residential). However, it can be seen from the list in Appendix G that for some chemical substances the Dutch intervention values are lower that the Canadian screening levels. This is especial true, when comparing with screening values for non-sensitive land use (e.g. Industrial and Commercial land use). To overcome this issue, the response levels should always be the highest specified level in Appendix E. In one important case, the Dutch Intervention Value is higher than the level in the Hazardous Waste Rules, namely for hexavalent Chromium, and in this case the Response Level will correspond to the level in the Hazardous Waste Rule (50 mg/kg).

Chemical Name	Chemical Groups	**Hazardous Waste** (levels Schedule II, HW Rules, 2008)[1)]	**Response levels** (Dutch Intervention levels)[2)]	**Soil (Screening and Response Levels)** — **Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				**Groundwater for drinking water (Screening levels)**			**Surface water Quality (Screening levels)** — The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial	Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
1,1,1-Trichloroethane (TCA)	Halogenated aliphatic compounds	5000	15	0,1	5	50	50	-	-	-					-	-
1,1,2,2- Tetrachloroethene (PCE)	Halogenated aliphatic compounds	5000	8,8	0,1	0,2	0,5	0,6	-	0.03	0,04	-	-	-	-	110	-
1,1,2,2-Tetrachlorethane	Halogenated aliphatic compounds	5000		0,1	5	50	50	-			-	-	-	-	-	-
1,1,2-Trichloroethane	Halogenated aliphatic compounds	5000	10	0,1	5	50	50	-	-		-	-	-	-	-	-
1,1,2-Trichloroethene (TCE)	Halogenated aliphatic compounds	5000	2,5	0,01	0,01	0,01	0,01	-	0.005	0,02	-	-	-	-	21	-/50
1,1-Dichloroethane	Halogenated aliphatic compounds	5000	15	0,1	5	50	50	-	-		-	-	-	-	-	-
1,1-Dichloroethene	Halogenated aliphatic compounds	5000	0,3	0,1	5	50	50	-	0.014		-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	1,8	-
1,2,3,5-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	-	-
1,2,3-Trichlorobenzene	Halogenated aromatic compounds	50	11	0,05	2	10	10	-	-		-	-	-	-	8	-
1,2,4,5-Tetrachlorobenzene	Halogenated aromatic compounds	50	2,2	0,05	2	10	10	-	-		-	-	-	-	-	-
1,2,4-Trichlorobenzene	Halogenated aromatic compounds	50	11	0,05	2	10	10	-	-		-	-	-	-	24	-
1,2-Dichlorobenzene	Halogenated aromatic compounds	50	19	0,1	1	10	10	-	-	1	-	-	-	-	0,7	-
1,2-Dichloroethane	Halogenated aliphatic compounds	5000	6,4	0,1	5	50	50	0,003	0.005	0,003	-	-	-	-	100	-/5
1,2-Dichloroethene	Halogenated aliphatic compounds	5000	1	0,1	5	50	50	-	-	0,05	-	-	-	-	-	-
1,2-Dichloropropane	Halogenated aliphatic compounds	5000	2	0,1	5	50	50	-	-	0,04	-	-	-	-	-	-
1,2-Dichloropropene (cis and trans)	Halogenated aliphatic compounds	5000		0,1	5	50	50	-	-		-	-	-	-	-	-
1,3,5-Trichlorobenzene	Halogenated aromatic compounds	50		0,05	2	10	10	-	-		-	-	-	-	-	-
1,3-Dichlorobenzene	Halogenated aromatic compounds	50		0,1	1	10	10	-	-		-	-	-	-	150	-
1,4-Dichlorobenzene	Halogenated aromatic compounds	50		0,1	1	10	10	-	0.005	0,3	-	-	-	-	26	-
1,4-Dioxane		-		-	-	-	-	-	-	0,05	-	-	-	-	-	-
2,3,4,6-Tetrachlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.1		-	-	-	-	-	-
2,4,6-Trichlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.005	0,2	-	-	-	-	-	-
2,4-Dichlorophenol	Halogenated aromatic compounds	50		0,05	0,5	5	5	-	0.9		-	-	-	-	-	-
2,4-Dichlorophenoxyacetic acid (2,4-D)	Pesticides (Phenoxy herbicide)	-		-	-	-	-	0,03	-	0,03	-	-	-	-	-	-
3-Iodo-2-propynyl butyl carbamate	Pesticides, Carbamate	-		-	-	-	-	-	-		-	-	-	-	1,9	-
Acenaphthene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	5,8	-
Acenaphthylene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	-	-
Acridine	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	4,4	-
Aldicarb	Pesticides, Carbamate	-		-	-	-	-	-	0.009	0,01	-	-	-	-	1	54,9/11
Aldrin	Pesticides, Organochlorine	50	0,32	-	-	-	-	0.00003	0.0007	0,00003	-	-	-	-	0.004	-
Aliphatics nonchlorinated (each)	Non-halogenated aliphatic compounds	-		0,3	-	-	-	-	-		-	-	-	-	-	-
Aluminium	Metal	-		-	-	-	-	0.03	-		-	-	-	-	Variable	5000/5000
Ammonia (total)	Inorganic	20000		-	-	-	-	0,5	-		5			5	Table	-
Ammonia (un-ionized)	Inorganic	-		-	-	-	-		-		-	-	-	-	19	-
Aniline	Organic	-		-	-	-	-		-		-	-	-	-	2,2	-
Anthracene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,012	-
Antimony (metallic)	Inorganic	50	22	20	20	40	40		0.006	0,02	-	-	-	-	-	-
Arsenic	Metal	50	50 (76)!	12	12	12	12	0,01	0.01	0,01	0,2	0,2	0,2	0,2	5	100/25
Asbestos		5000	100	-	-	-	-		-		-	-	-	-		-
Atrazine	Pesticides, Triazine	-	0,71	-	-	-	-	0.002	0.005	0,002	-	-	-	-	1,8	10/5
Barium	Inorganic	20000	-	750	500	2000	2000	0.7	1.0	0,7	-	-	-	-	-	-
Benzene	Monocyclic aromatic compounds	50	1.1	0.05 ¤	0.5 ¤	5 ¤	5 ¤		0.005		0,01*	-	0,01*	0,01*	370	-
Benzo(a)anthracen	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,018	-

Chemical Name	Chemical Groups	**Hazardous Waste** (levels Schedule II, HW Rules, 2008)[1)]	**Response levels** (Dutch Intervention levels)[2)]	**Soil (Screening and Response Levels)** **Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				**Groundwater for drinking water (Screening levels)** Indian Standard for Drinking Water * (Maximum acceptable concentration)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	**Surface water Quality (Screening levels)** The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Benzo(a)pyrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		0.00001		-	-	-	-	0,015	-
Benzo(b)fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Benzo(k)fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Beryllium	Inorganic	50		4	4	8	8		-		-	-	-	-	-	100/100
Boron	Inorganic	-		2	-	-	-	0,5	5.0		-	-	-	-	1.5mg/L	5000/5000
Bromacil	Pesticides	-		-	-	-	-		-		-	-	-	-	5	0,2/1100
Bromoxynil	Pesticides, Benzonitrile	-		-	-	-	-		0.005		-	-	-	-	5	0,33/11
Cadmium	Metal	50	13	1,4	10	22	22	0.003	0.005		2	1	-	2	Equation	5,1/80
Calcium	Inorganic	-		-	-	-	-	75	-		-	-	-	-	-	-/1000000
Captan	Pesticides	-		-	-	-	-		-		-	-	-	-	1,3	-/13
Carbaryl	Pesticides, Carbamate	-	0,45	-	-	-	-		-		0.01	-	0.01	0.01	0,2	-/1100
Carbofuran	Pesticides, Carbamate	-	0,017	-	-	-	-		0.09		-	-	-	-	1,8	-/45
Chlordane	Pesticides, Organochlorine	50	4	-	-	-	-		-		-	-	-	-	0.006	-/7
Chloride	Inorganic	-		-	-	-	-	250	-		-	-	-	-	or 120 mg/L	Variable/-
Chlorothalonil	Pesticides	-		-	-	-	-		-		-	-	-	-	0,18	crops)/170
Chlorpyrifos	Pesticides, Organophosphorus	5000		-	-	-	-	0,03	0.09	0,03	-	-	-	-	0,002	-/24
Chromium (total)	Metal	-	-	64	64	87	87		0.05	0,05	2	2	-	2	-	-
Chromium, hexavalent (Cr(VI))	Metal	50	50 (78)!	0,4	0,4	1,4	1,4	0.05	-		0,1	2	-	1	1	8/50
Chromium, trivalent (Cr(III))	Metal	5000	180	-	-	-	-		-		-	-	-	-	8,9	4,9/50
Chrysene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	-	-
Cobalt	Inorganic	5000	190	40	50	300	300		-		-	-	-	-	-	50/1000
Coliforms, fecal (Escherichia coli)	Biological	-		-	-	-	-		-		-	-	-	-	-	mL/-
Coliforms, total	Biological	-		-	-	-	-				-	-	-	-	-	mL
Colour	Physical	-		-	-	-	-	5 Hazen Units	-		-	-	-	-	Narrative	-
Conductivity	Physical	-		2 dS/m	2 dS/m	4 dS/m	4 dS/m		-		-	-	-	-	-	-
Copper	Metal	5000	190	63	63	91	91	0.05	-	2	3	3	-	3	Equation	Variable/variable
Cyanazine	Pesticides, Triazine	-		-	-	-	-		0.01	0,0006	-	-	-	-	2	0,5/10
Cyanide	Inorganic	50	50	0,9	0,9	8	8	0.05	0.2	0,07	0,2	2	0,2	0,2	5 (as free CN)	-/-
Cyanobacteria	Biological	-		-	-	-	-	-	0.0015		-	-	-	-	-	-/-
Debris	Physical	-		-	-	-	-	-	-		-	-	-	-	-	-/-
Deltamethrin	Pesticides	-		-	-	-	-	-	-		-	-	-	-	0,0004	-/2.5
Di(2-ethylhexyl) phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	16	-/-
Di-n-butyl phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	19	-/-
Di-n-octyl phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	-	-/-
Dibenz(a,h)anthracene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	-	-/-
Dibromochloromethane	Halogenated methanes	5000		-	-	-	-	0.1	-		-	-	-	-	-	-/100
Dicamba	Pesticides, Aromatic Carboxylic Acid	-		-	-	-	-		-		-	-	-	-	10	0,006/122
DDT Total (Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	Pesticides, Organochlorine	50	1,7	0,7	0,7	12	12	0,001	-	0,001	10*)	-	10*)	10*)	0.001	-/30
DDD (Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane)	Pesticides, Organochlorine	50	34	-	-	-	-	0,001	-	0,001	-	-	-	-		-

Chemical Name	Chemical Groups	**Hazardous Waste** (levels Schedule II, HW Rules, 2008)[1)]	**Soil (Screening and Response Levels)**					**Groundwater for drinking water (Screening levels)**			**Surface water Quality (Screening levels)**					
			Response levels (Dutch Intervention levels) [2)]	**Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				Indian Standard for Drinking Water * (Maximum acceptable concentration)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commercial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
DDE (Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene)	Pesticides, Organochlorine	50	2,3	-	-	-	-	0,001	-	0,001	-	-	-	-		-
DDT (Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane)	Pesticides, Organochlorine	50	1,7	-	-	-	-	0,001	-	0,001	-	-	-	-		-
Dichlorobromomethane	Halogenated methanes	5000		-	-	-	-	-	-		-	-	-	-	-	-/100
Dichloromethane (Methylene chloride)	Halogenated aliphatic compounds	5000	3,9	0,1	5	50	50	-	0.05	0,02	-	-	-	-	98,1	-/50
Dichlorophenols	Chlorinated phenols	50	22	0,05	0,5	5	5	-	0.9		-	-	-	-	0,2	
Diclofop-methyl	Pesticides	-		-	-	-	-	-	-		-	-	-	-	6,1	0,18/9
Didecyl dimethyl ammonium chloride	Pesticides	-		-	-	-	-	-	-		-	-	-	-	1,5	-
Dieldrin	Pesticides, Organochlorine	50	-	-	-	-	-	0.00003	-	0.00003	-	-	-	-		-
Diethylene glycol	Glycols	-		-	-	-	-	-	-		-	-	-	-	-	-
Diisopropanolamine	Organic	-		180	180	180	180	-	-		-	-	-	-	1600	2 000/-
Dimethoate	Pesticides, Organophosphorus	5000		-	-	-	-	-	-	0,006	-	-	-	-	6,2	-/3
Dinoseb	Pesticides	-		-	-	-	-	-	0.01		-	-	-	-	0,05	16/150
Dissolved gas supersaturation	Physical	-		-	-	-	-	-	-		-	-	-	-	Narrative	-
Dissolved oxygen	Inorganic	-		-	-	-	-		-		-	-	-	-	-	-
Endosulfan	Pesticides, Organochlorine	50	4	-	-	-	-	0.0004	-		10*)	-	10*)	10*)	0,003	-
Endrin	Pesticides, Organochlorine	50	-	-	-	-	-		-	0,0006	-	-	-	-	0.0023	-
Ethylbenzene	Monocyclic aromatic compounds	20000	110	0.1	5	50	50		-	0,3	-	-	-	-	90	-/2.4
Ethylene glycol	Glycols	-		960	960	960	960		-		-	-	-	-	192 000	-
Fluoranthene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,04	-
Fluorene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	3	-
Fluorine		5000		-	-	-	-		-		-	-	-	-		-
Fluoride	Inorganic	5000		200	400	2000	2000	1.0	1.5	1,5	2	15	-	15	120	1000/variable
Glyphosate	Pesticides, Organophosphorus	5000		-	-	-	-		0.28		-	-	-	-	800	-/280
Heptachlor	Pesticides, Organochlorine	50	4	-	-	-	-		-		-	-	-	-	0.01	-/3
Hexachlorobenzene	Halogenated aromatic compounds	50	2	0,05	2	10	10		-		-	-	-	-	-	-/0.52
Hexachlorobutadiene	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	1,3	No data
Hexachlorocyclohexane (HCH)	Pesticides, Organochlorine	50	-	0,01	-	-	-		-		-	-	-	-	0,01	-/4
Hexachlorocyclohexane (alfa HCH)	Pesticides, Organochlorine	-	17	-	-	-	-		-		-	-	-	-		
Hexachlorocyclohexane (beta HCH)	Pesticides, Organochlorine	-	1,6	-	-	-	-		-		-	-	-	-		
Hexachlorocyclohexane (delta HCH)	Pesticides, Organochlorine	-		-	-	-	-		-		-	-	-	-		
Hydrazine(s)		5000							-		-	-	-	-		-
Imidacloprid		-		-	-	-	-		-		-	-	-	-	0,23	-
Indeno(1,2,3-c,d)pyrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	No data	-
Iron	Inorganic	-		-	-	-	-	0.3			3	3	-	3	300	5000/'-
Lead	Metal	5000	530	70	140	260	600	0.01	0.01		0,1	1	-	2	Equation	200/100
Lindane (gamma HCH)	Pesticides, Organochlorine	50	1,2	-	-	-	-	0.002	-		-	-	-	-		
Linuron	Pesticides	-		-	-	-	-		-		-	-	-	-	7	0,071/-
Lithium	Inorganic	-		-	-	-	-		-		-	-	-	-	-	2500/-
Malathione	Pesticide, Organophosphorus	5000		-	-	-	-	0.19	0.19		10	-	10	10		-
Manganese	Inorganic	-		-	-	-	-	0.1			2	2	-	2	-	200/-

Chemical Name	Chemical Groups	**Hazardous Waste** (levels Schedule II, HW Rules, 2008)[1)]	**Response levels** (Dutch Intervention levels)[2)]	Soil (Screening and Response Levels) — **Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				Groundwater for drinking water (Screening levels)			Surface water Quality (Screening levels) — The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
				Agricultural	Residential/-parkland	Commer-cial	Industrial	Indian Standard for Drinking Water * (Maximum acceptable concentra-tion)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Mercury (inorganic)	Metal	50	36	6,6	6,6	24	50	0.001	0.001		0,01	0,01	-	0,01	0,026	-
Methoprene		-		-	-	-	-		-		-	-	-	-	Organism	-
Methyl tertiary-butyl ether (MTBE)	Aliphatic ether	-		-	-	-	-		-		-	-	-	-	10 000	-
MCPA (Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid)	Pesticides	-	4	-	-	-	-		0.1		-	-	-	-	2,6	0,025/25
Methylmercury	Organic	5000		-	-	-	-		-						0,004	-
Methylparathion	Pesticide, Organophosphorus	5000		-	-	-	-	0.0003	-		10	-	10	10		-
Metolachlor	Pesticide, Organophosphorus	50		-	-	-	-		0.05						7,8	28/50
Metribuzin	Pesticides, Triazine	-		-	-	-	-		0.08		-	-	-	-	1	0,5/80
Molybdenum	Inorganic	5000	190	5	10	40	40	0.07	.-	0,07	-	-	-	-	73	Narrative/500
Monobromomethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-
Monochlorobenzene	Halogenated aromatic compounds	50	15	0,1	1	10	10		0.08		-	-	-	-	1,3	-
Monochloromethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-
Monochlorophenols	Chlorinated phenols	50	5,4	0,05	0,5	5	5		-		-	-	-	-	7	-
Naphthalene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	1,1	-
Nickel	Metal	5000	100	50	50	50	50	0.02	-	0,07	3	3	-	5	Equation	200/1000
Nitrate	Inorganic nitrogen compounds	20000		-	-	-	-	45	45	50	10	-	-	20	13 mg/L	-
Nitrate + Nitrite	Inorganic nitrogen compounds	20000		-	-	-	-		-		-	-	-	-	-	NO3+NO2-N
Nitrite	Inorganic nitrogen compounds	5000		-	-	-	-		-	3	-	-	-	-	60 NO2-N	-/10 000 NO2-N
Nonylphenol and its ethoxylates	Nonylphenol and its ethoxylates	-		5,7	5,7	14	14		-		-	-	-	-	1	-
Nutrients		-		-	-	-	-		-		-	-	-	-	Framework	-
n-hexane	Aliphatic hydrocarbon	-		0.49/6.5 #	0.49/6.5 #	6.5/21 #	6.5/21 #		-		-	-	-	-	-	-
Parathione	Pesticide, Organophosphorus	5000							-		-	-	-	-		-
Pentachlorobenzene	Halogenated aromatic compounds	50	6,7	0,05	2	10	10		-		-	-	-	-	6	-
Pentachlorophenol	Halogenated aromatic compounds	50	12	7,6	7,6	7,6	7,6		0.06	0,009	-	-	-	-	0,5	-
Permethrin	Pesticides, Organochlorine compounds	50		-	-	-	-		-		-	-	-	-	0,004	-
Phenanthrene	Polycyclic aromatic hydrocarbons (PAH)	50		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,4	-
Phenolic compounds (as C6H5OH)	compounds	5000	14	0,1	1	10	10	0.001	-		1	5	-	5	-	-
Phenols (mono- & dihydric)	Aromatic hydroxy compounds	5000		3,8	3,8	3,8	3,8		-		-	-	-	-	4	-/2
Phenoxy herbicides	Pesticides	-		-	-	-	-		-		-	-	-	-	4	-/100
Phosphorus (as P)	Inorganic	20000		-	-	-	-		-		5	-	-	-	Framework	-
Phthalic acid esters (each)	Phthalate esters	-		30	-	-	-		-		-	-	-	-	-	-
Picloram	Pesticides	-		-	-	-	-		-		-	-	-	-	29	-/190
PCBs (Polychlorinated biphenyls)	Polychlorinated biphenyls	50	1	0,5	1,3	33	33	0.0005	-		-	-	-	-	0.001	-
Poly cyclic Hydrocarbon (PAH)	Polycyclic aromatic hydrocarbons (PAH)	-	40					0.0001	-		-	-	-	-	-	-
Polychlorinated dibenzo-p-dioxins/dibenzo furans	Polychlorinated dioxins and furans	-	0,00018	4 ng TEQ.kg-1	4 ng TEQ.kg-1	4 ng TEQ.kg-1	4 ng TEQ.kg-1		-		-	-	-	-	-	-
Propylene glycol	Glycols	-		-	-	-	-		-		-	-	-	-	500 000	-
Pyrene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	0,025	-
pH	Inorganic Acidity, alkalinity and pH	-		6 to 8	6 to 8	6 to 8	6 to 8	6.5-8.5			5,5 - 9,0	5,5 - 9,0	5,5 - 9,0	5,5 - 9,0	6.5 to 9.0	-
Quinoline	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤		-		-	-	-	-	3,4	-
Reactive Chlorine Species	Inorganic Reactive chlorine compunds	-		-	-	-	-		-		-	-	-	-	0,5	-
Salinity	Physical	-		-	-	-	-		-		-	-	-	-	-	-

Chemical Name	Chemical Groups	**Hazardous Waste** (levels Schedule II, HW Rules, 2008)[1)]	**Response levels** (Dutch Intervention levels)[2)]	**Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				Indian Standard for Drinking Water * (Maximum acceptable concentration)	Guidelines for Canadian Drinking Water Quality	WHO guidelines for Drinking water	The Environment (Protection) Rules, 1986 Schedule VI General standards for discharge of environmental pollutants				Canadian Water Quality Guidelines for the Protection of **Aquatic Life**	Canadian Water Quality Guidelines for the Protection of **Agriculture**
		Hazardous Waste	Soil (Screening and Response Levels)					Groundwater for drinking water (Screening levels)			Surface water Quality (Screening levels)					
				Agricultural	Residential/-parkland	Commer-cial	Industrial				Inland surface water	Public sewers	Land for irrigation	Marine coastal areas	Longterm in Freshwater	Irrigation/-Livestock
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/L	µg/L
Selenium	Inorganic	50		1	1	2,9	2,9	0.01	0.01	0,01	0,05	0,05	-	0,05	1	Variable/50
Silver	Inorganic	5000		20	20	40	40	0,1	-		-	-	-	-	0,1	-
Simazine	Pesticides, Triazine	-		-	-	-	-		0.01	0,002	-	-	-	-	10	0,5
Sodium adsorption ratio		-		5	5	12	12		-		-	-	-	-	-	-
Streambed substrate	solids Total particulate matter	-		-	-	-	-		-		-	-	-	-	Narrative	-
Styrene	Monocyclic aromatic compounds	20000	86	0,1	5	50	50		-	0,02	-	-	-	-	72	-
Sulfolane	Organic sulphur compound	-		0,8	0,8	0,8	0,8		-		-	-	-	-	50 000	500
Sulphate	Inorganic Inorganic sulphur compounds	-		-	-	-	-	200	-		-	-	-	-	-	No data
Sulphur (elemental)	Inorganic Inorganic sulphur compounds	50000		500	-	-	-		-		-	-	-	-	-	-
Suspended sediments	solids Total particulate matter	-		-	-	-	-		-		-	-	-	-	Narrative	-
Tebuthiuron	Pesticides	-		-	-	-	-		-		-	-	-	-	1,6	tame hays, and
Tellurium		50		-	-	-	-		-		-	-	-	-		-
Temperature	Physical Temperature	-		-	-	-	-		-		above				Narrative	-
Tetrachloromethane	Halogenated aliphatic compounds	5000	0,7	0,1	5	50	50		-		-	-	-	-	13,3	-/5
Tetrachlorophenols	Halogenated aromatic compounds	50	21	0,05	0,5	5	5		0.1		-	-	-	-	1	-
Thallium	Inorganic	50		1	1	1	1		-		-	-	-	-	0,8	-
Thiophene	Miscellaneous organic compound	-		0,1	-	-	-		-		-	-	-	-	-	-
Tin (inorganic)	Inorganic	5000		5	50	300	300		-		-	-	-	-	-	-
Tin (organic)		50		-	-	-	-		-		-	-	-	-	-	-
Toluene	Monocyclic aromatic compounds	20000	32	0.1	3	30	30		-	0,7	-	-	-	-	2	-/24
Total dissolved solids (TDS)	solids	-		-	-	-	-	500	-		100	600	200	100	-	00
Total hydrocarbons (TPH) (mineral oil)		50000	5000	-	-	-	-	0,5	-		10	20	10	20	-	-
Toxaphene	Pesticides, Organochlorine	50		-	-	-	-		-		-	-	-	-	0.008	-/5
Triallate	Pesticides, Carbamate	-		-	-	-	-		-		-	-	-	-	0,24	-/230
Tribromomethane	Halogenated aliphatic compounds	5000		-	-	-	-		-		-	-	-	-	-	-/100
Tributyltin	Organotin compounds	50		-	-	-	-		-		-	-	-	-	0,008	-/250
Trichlorfon		-		-	-	-	-		-		-	-	-	-	0,009	-
Trichloromethane (chloroform)	Halogenated aliphatic compounds	5000	0,7	0,1	5	50	50	0,2	-	0,3	-	-	-	-	1,8	-/100
Trichlorophenols	Halogenated aromatic compounds	50	22	0,05	0,5	5	5		0.005		-	-	-	-	18	-
Tricyclohexyltin	Organotin compounds	-		-	-	-	-		-		-	-	-	-	-	-/250
Trifluralin	Pesticides, Dinitroaniline	-		-	-	-	-		-	0,02	-	-	-	-	0,2	-/45
Triphenyltin	Organotin compounds	50		-	-	-	-		-		-	-	-	-	0,022	-/820
Turbidity	solids Total particulate matter	-		-	-	-	-	1 NTU	0.1-1.0 NTU		-	-	-	-	Narrative	-
Tungsten compounds		5000		-	-	-	-		-		-	-	-	-	-	-
Uranium	Inorganic	-		23	23	33	300		0.0s	0,015	-	-	-	-	15	10/200
Vinylchloride	Halogenated aliphatic compounds	5000	0,1	-	-	-	-		0.002	0,0003	-	-	-	-	-	-
Vanadium	Inorganic	5000		130	130	130	130		-		0,2	0,2	-	0,2	-	100/100
Xylene	Monocyclic aromatic compounds	20000	17	0.1	5	50	50		-	0,5	-	-	-	-	-	-
Zinc	Metal	20000	720	200	200	360	360	5	-		5	15	-	15	30	-/50000

NR: No relaxation

[1)]: Schedule 2 of the Hazardous Waste Rules (2008); [2)]: Circulaire bodemsanering (Soil Remediation Circular, 2013)

¤: CCME (Canadian Council of Ministers of the Environment). 1991. Interim Canadian environmental quality criteria for contaminated sites. CCME, Winnipeg.

#: coarse/fine sediment

!: xx (yy): xx is value from HWR 2008; yy is Dutch Intervention values. In this case levels from HWR are used because these are lowest

*: IS: 10500:2012

Volume III

2.2-i Manual Conceptual Site Model and identifying the Source-Pathway-Receptor

Volume III-2.2-i
Manual Conceptual Site Model and identifying the Source-Pathway-Receptor

1 Introduction

This information is most relevant for Steps 2 (Task 2.2 Preliminary site investigation), 5 (Task 5.1 Detailed site investigation) and 6 (Remediation design, DPR).
This Section presents two internationally widely used concepts in site assessment, the Source-Pathway-Receptor (SPR) approach and the Conceptual Site Model (CSM). These two concepts are closely connected.

Using a CSM it is possible to characterize the physical, biological, and chemical systems existing at a site. The processes that determine contaminant releases, contaminant migration, and environmental receptor exposure to contaminants are described and integrated in a conceptual site model.
The conceptual site model should be used to enable experts from all disciplines to communicate effectively with one another, resolve issues concerning the site, and facilitate the decision-making process.

This section explains how to assist in the development of a CSM. At the end of this section reference is made to background information. Because the ASTM-1689-guideline provides clear information this guideline is mostly referred to in the below text.

2 The Source-Pathway-Receptor approach

The Source-Pathway-Receptor approach is used in site investigation and risk assessment to identify the source of any contamination, what the source may affect (receptor) and how the source may reach the receptor (pathway). The SPR concept is a fundamental and internationally widely accepted approach to assess contaminated sites and develop remediation options.

The three elements of this SPR concept are:

- Source (S): The cause or potential source of the contamination is identified and investigated. These sources might include all activities described in the Typology. Contaminants of concern as well as their concentrations in the various media on site require full characterization to understand the extent and potential for migration.
- Pathway (P): The pathway is the route by which the compounds of the contaminants are migrating from the source to the receptor. Pathways include air, water, soil, animals, vegetables and eco-systems. Potential migration pathways for the identified and characterized contaminants to receptors are then identified and evaluated to assess exposure risks. If direct contact of the Receptor with the source is present, the pathway is part of the source.
- Receptor (R): If contamination is to cause harm, it must reach a receptor. A receptor is a person, animal, plant, eco-system, property or a controlled (ground or surface) water. Each receptor must be identified and their sensitivity to the contaminant must be established. Consideration should be given to on-site as well

as off-site receptors. An example of an off-site receptor are individuals who receive exposure via consumption of drinking water which is obtained from a location down gradient of the contaminated source.

For one site several SPR-combinations can be applicable. Each SPR-combination can be subject to remediation. The risk assessment will define if remediation of a specific SPR-combination is needed. Without a SPR-combination, no risks can be identified, even if contaminations in soil, groundwater, surface water, sediment or air are present above certain levels. The analysis of the SPR-combination is therefore essential for the risk assessment.

3 The Conceptual Site Model (CSM)

Conceptual site models are commonly used to implement a structured and efficient investigation. Preparation and use of the conceptual site model is an iterative process throughout the lifecycle of the remediation project. It starts with the generic typology of the contaminated site during the preliminary investigation which will be extended with information of a specific site (see Glossary for an explanation on typology). As new data become available during the detailed site investigation and the risk assessment, the conceptual site model is modified to continually evaluate the connection between sources of contaminants, migration pathways, and receptors. Evaluation of these three components through the use of the conceptual site model in conjunction with initial preparation and subsequent revisions ensures receptors are identified and addressed. The CSM enables integration of all site information, identification of data needs and guiding of data collection activities. Possible uncertainties in the CSM should be mentioned clearly in order to decide if additional data should be collected.

Where the CSM is used to develop remediation options, the remediation techniques can be designed in such a way that the effects meet an optimum by balancing the intensity of a technique over the three elements of a specific site. The CSM can even be used during the site remediation when reporting on the results and on the achievement of the remediation objectives.

The site for which a CSM is developed should be able to be delineated clearly from other contaminated sites. If individual contaminated sites are in the proximity to one another and individual sources cannot be determined sites may be aggregated in that case and a conceptual model should then be developed for the aggregate.

Following activities have to be carried out in development of a CSM:

- Assembling Information by desk study and site visit: Assemble historical and current site-related information on topography, land use, hydrology and (hydro)geology from maps, aerial images, cross sections, environmental data, records, reports, studies, and other information sources. These activities are described in the Site Inspection Protocol (Volume III-2.1-i). This information should comprise the current and future use of the site.
- Identifying contaminating substances in the soil, groundwater, surface water, sediments, biota, and air. Provide description of the characteristics (a.o. density, solubility, volatility, biodegradability) and behavior in media.

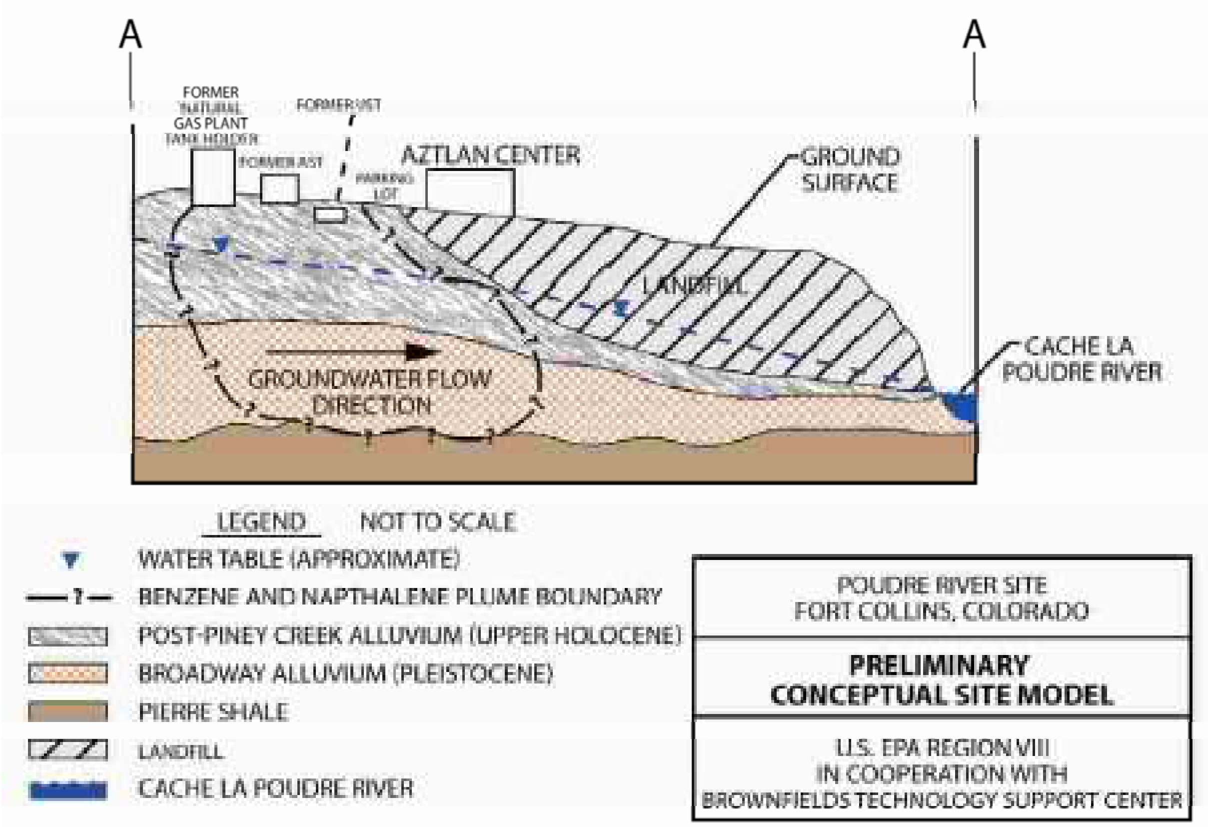
- Establishing Background Concentrations of Contaminants: This is important for the following reasons:
  a. to establish the range of concentrations of certain parameters present at the site due to natural occurrence;
  b. to help establish the extent to which contamination exceeds background levels and the area where this occurs.
- Identifying and characterizing Source: the following source characteristics should be measured or estimated for a site, the level of detail depends on the position in the process of assessment and remediation. During detailed site assessment these elements should be considered more detailed compared to the CSM during preliminary site assessment:
  - Source location(s), boundaries, and volume(s);
  - The potentially hazardous constituents and their concentrations in media at the source;
  - The time of initiation, duration, and rate of contaminant release from the source.
- Identifying Pathways: Potential migration pathways by which contaminants are migrating through groundwater, surface water, air, soils, sediments, and biota should be identi ed for each source. A diagram of exposure pathways for all source types at a site may help to structure and illustrate the collected information (see the description of task 5.2 in Volume I).
- Identifying Receptors: Identify receptors currently or potentially exposed to site contaminants. This includes humans and other organisms that are in direct contact with the source of contamination, potentially present along the migration pathways, or located in the vicinity of the site.

The results of the CSM can be described, summarized in a table and/or illustrated in 2D or 3D pictures. Some examples are provided below a.o. for the Ranipet site near Chennai, Tamil Nadu:

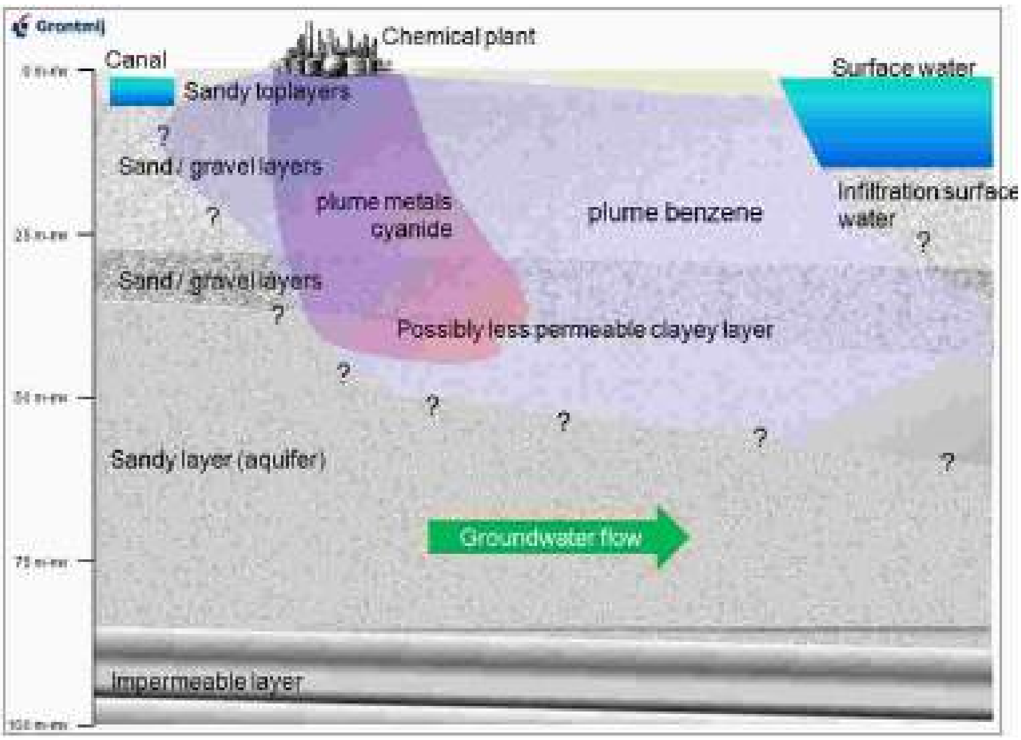
References to more detailed information on SPR and CSM

- Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface: http://www.google.nl/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&ved=0CDEQFjAA&url=http%3A%2F%2Fwww.sepa.org.uk%2Fland%2Fidoc.ashx%3Fdocid%3D348518fc-6662-4699-8e7a-4b28d5cd64c9%26version%3D-1&ei=Sy7YUJa1LoLRhAfwuoGIBQ&usg=AFQjCNGbsmFOnTvTZBOPwZDfqS7t8HCxnA
- ASTM E1689 - 95(2008) Standard Guide for Developing Conceptual Site Models for Contaminated Sites: http://www.astm.org/Standards/E1689.htm (not freely accessible data).
- Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model: EPA 542-F-11-011 July 2011
- Public Health Assessment Guidance Manual, Agency for Toxic Substances and Disease Registry, January 2005, http://www.atsdr.cdc.gov/hac/PHAManual/PDFs/PHAGM_final1-27-05.pdf

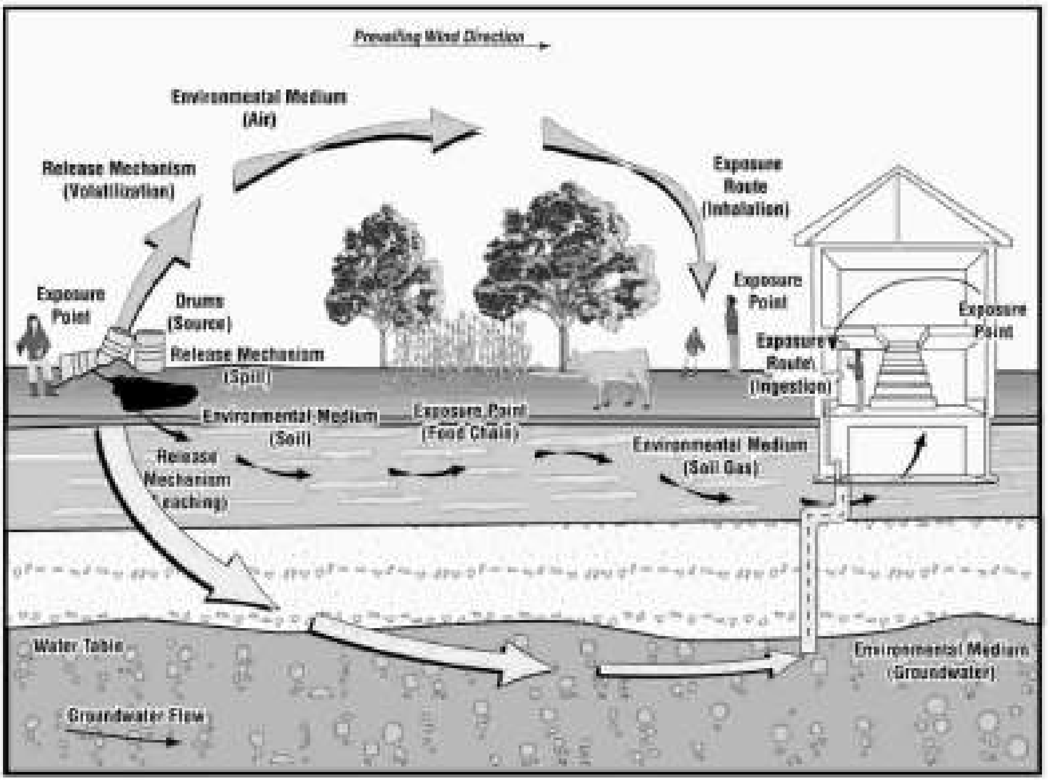
Example of Preliminary CSM Representation from US EPA July 2011



Example of 2-D Characterization CSM



Example of 2-D Characterization CSM



Example of a schematic exposure pathway in a Conceptual Site Model (source: Public Health Assessment Guidance Manual, Agency for Toxic Substances and Disease Registry, 2005)

Example of collection information and development of CSM w.r.t. Ranipet Site:

List of references for soil / subsurface data needed in site, risk and remediation option assessment					
Type of data needed	**Comments**	**Example elements in the site assessment the data is used for**	**Data sources available**	**Quality of data**	**Scale of data**
Soft soil subsurface					
Composition *)	e.g. clay, sand	spreading of contaminants: pathway layout risk assessment	General Soil Map India, 1:20.000.000, Indian Minister of Agriculture, 1998	Highly detailed study based on recent field measurements and laboratory analyses giving the standardized reference of soil quality and composition	Not applicable on site-scale but very useful for a general picture of the site and its surroundings
Alfisol : Haplustalfs, Paleustalfs, Rhodustalfs	reddish brown gravelly clay/sandy soil Riverine Land Form; Alluvium/Laterite (RECENT / PLEISTOCENE)	Spreading of Hexavalent Chromium from Chromium Ore Processing Residue to subsurface and leaching to ground water due during rains	Soil Map of India; Scale 1:6,000,000; Map Ref: INDI 5; All India Soil and Land Use Survey; Indiana Agricultural Research Institute; Govt. of India, 1971 and Soil Regions, Southern India Plate 203, National Atlas of India; Scale 1:2,000,000; Dept. of Science & Technology; Govt. of India, 1981 and Tamil Nadu Soils, Sheet 1 and 2; Scale 1:500,000; Survey of India Map; Govt. of India, 1996.	High Quality Maps of Govt. of India Map Reference is also given to: ISRIC, Wageningen, The Netherlands	Not applicable on site-scale but very useful for a general picture of the site and its surroundings
% organic matter *)		spreading of contaminants: adsorption of organic contaminants			

		capacity of NA			
% clay minerals *)		spreading of contaminants: retardation of heavy metal (adsorption)			
Permeability *)	if possible in m/day	spreading of contaminants: speed of spreading and assessment of pump and treat options			
High permeability					
Type of sedimentary deposition	e.g. river delta deposit, river plain deposit. If possible a detailed description.	spreading of contaminants: pathway layout design of in situ options			
Layering	Vertical variations in soil composition	spreading of contaminants: pathway layout design of in situ options			
Depth of soil/bedrock transition		spreading of contaminants: pathway layout			
1m			NGRI Report October 2008	High Quality	Applicable to site
Horizontal discontinuities	Horizontal variations in soil composition	spreading of contaminants: pathway layout			
Bedrock subsurface					
Type of rock		spreading of contaminants: pathway layout			
Achaean Granite with highly metamorphosed gneissic complex basement Alluvium, granite, gneisses and charnockite	Secondary structures like joints and fractures due to tectonic activity and intrusion of dolerite dykes and quartz Veins	Compacted Chromium upto 2m depth	NGRI Report October 2008 and DISTRICT GROUNDWATER BROCHURE VELLORE DISTRICT, TAMIL NADU- Technical Report Series, Central Ground Water Board, South Eastern Coastal Region, Chennai, January 2009	High Quality	Applicable to site and also very useful for a general picture of the site and its surroundings
Permeability		spreading of contaminants: pathway layout			
Highly		Chromium	NGRI Report	High Quality	Applicable to

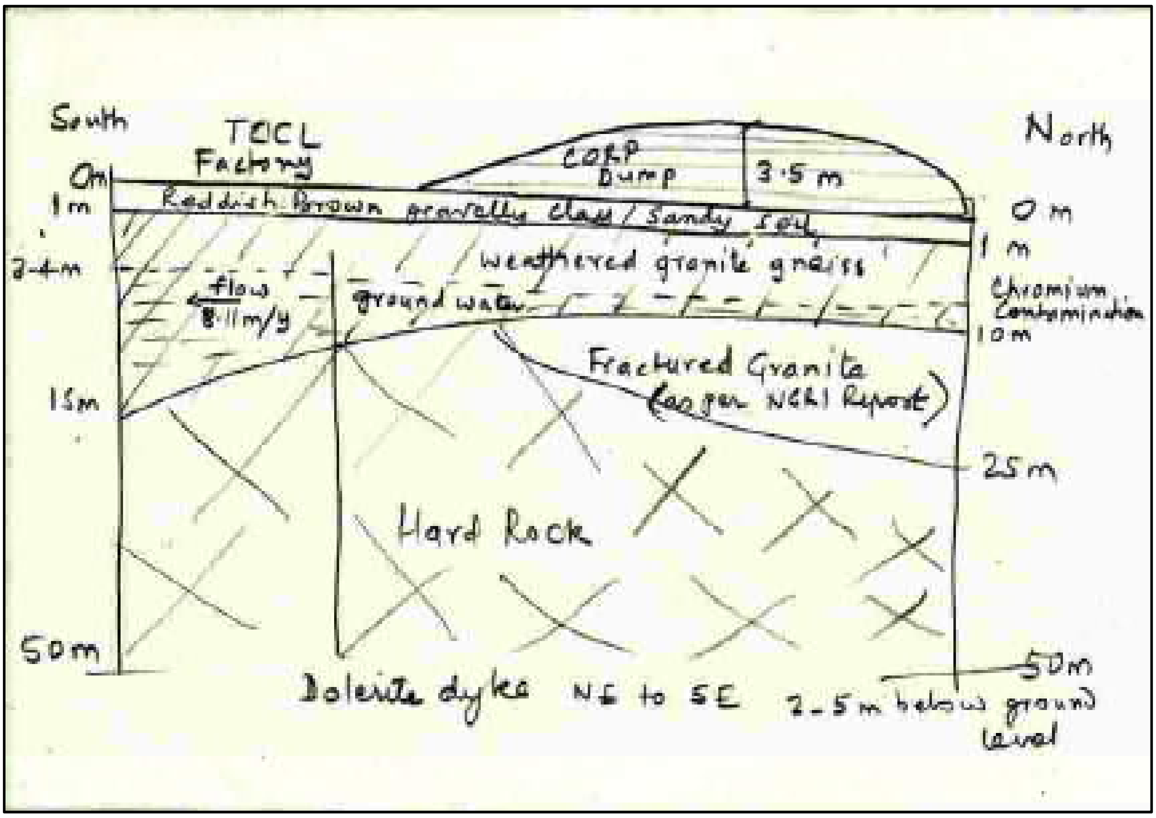
permeable		concentration decreases from average 200mg/kg at 1m depth to less than 50mg/kg at 5m depth	October 2008		site
Porosity		spreading of contaminants: pathway layout			
Weathering:					
thickness of weathered layer		spreading of contaminants: pathway layout			
10 to 15m	Weathered Granite gneiss	Chromium	NGRI Report October 2008	High Quality	Applicable to site
degree of weathering		spreading of contaminants: pathway layout			
22.50%	Weathered Granite gneiss		NGRI Report October 2008	High Quality	Applicable to site
Layering	Vertical variations in type of rock	spreading of contaminants: pathway layout			
Horizontal discontinuities	Horizontal variations in type of rock	spreading of contaminants: pathway layout			
Dolerite Dyke from 2 to 5m below ground level	NE to SE in the dumpsite	Subsurface barrier for groundwater movement and Chromium leaching	NGRI Report October 2008	High Quality	Applicable to site
Groundwater					
Head *)	Water table	risk assessment, pathway layout			
3 to 4 meter below ground level	Fracture granites, gneisses and charnockites		NGRI Report October 2008 and DISTRICT GROUNDWATER BROCHURE #)	High Quality	Applicable to site and also very useful for a general picture of the site and its surroundings
Groundwater flow *)					
Direction		spreading direction contaminants			
North to South	Follows topography		NGRI Report October 2008	High Quality	Applicable to site
Velocity		speed of spreading contaminants			
8.11m/year	Effective porosity value of 22.5%		NGRI Report October 2008	High Quality	Applicable to site

Chemical composition *)	general components like salts, O2 etc.	Risk assessment, capacity of NA of groundwater			
Total Hardness as $CaCO_3$ Chlorides Nitrates	More than permissible limit	Contamination of Chromium	DISTRICT GROUNDWATER BROCHURE #)	High Quality	Not applicable on site-scale but very useful for a general picture of the site and its surroundings
Pre Monsoon Water Level, m below ground level Post Monsoon Water Level, m below ground level Long Term Water Level Trend in 10 years, m/year	1.18 to 18.86 1 to 18.45 Annual Rise: min. 0.0025, max. 0.5264 Annual Fall: min. 0.0568, max. 2.3958		DISTRICT GROUNDWATER BROCHURE #)	High Quality	Not applicable on site-scale but very useful for a general picture of the site and its surroundings
Site use:					
Secured former industrial site	7.41 acres		Site visit 2012	High Quality	Applicable to site
To south:	500 m distance: small village and pasture with cattle; 4.5 m distance: river Palar				
North, West, East:	Industrial premises (still active)				
Pathways:					
Groundwater	Seepage of rain through waste material into underlying soil; transport of contamination through groundwater in horizontal direction to south;				
Surface water	runoff of rainfall with contaminated particles to				

	drainage ditches				
air	Possibly dust from not covered waste material				
Receptors:					
Residents village	Groundwater presently doesn't seem to be used		Site visit 2012		
Cattle related to community	Drinking surface water		Site visit 2012		
River Palar	Transport contaminated groundwater towards river		Report		
Plants and animals	Direct contact with contaminated soil, groundwater or surface water (outside industrial premises)		Site visit 2012		

Explanation:
*) if possible specified for each individual layer
#) DISTRICT GROUNDWATER BROCHURE, VELLORE DISTRICT, TAMIL NADU-Technical Report Series, Central Ground Water Board, South Eastern Coastal Region, Chennai, January 2009

Sketch of CSM from above data:



Volume III

2.2-ii Protocol investigation strategy preliminary site investigation

Volume III-2.2-ii
Protocol investigation strategy preliminary site investigation

1 Introduction

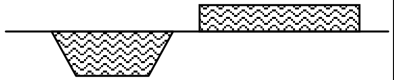
This information is most relevant for Task 2.2 preliminary site investigation.
The starting point for the preliminary site investigation is the typology of the contaminated site. For each type of contamination a different investigation strategy is recommended in order to achieve the investigation objective efficiently. The objective of a preliminary site investigation is to identify all sources of contamination and the relevant pathways to the receptors of concern.
When investigating a site a specific investigation protocol should be developed based on the typology. This site specific investigation protocol should pay attention to the following elements:

- Screening and sampling technical equipment;
- Sampling pattern and depth of samples, number of samples and use of composite samples;
- Analytical test parameters / determinants required;
- Quality Assurance / Quality Control procedures such as use of field blanks/trips blanks, procedures to avoid cross contamination by sampling equipment etc.

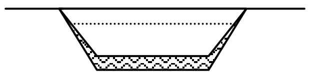
The table below provides a basis for the field investigation strategy including the sampling pattern based on the typology of the contamination and its field characteristics. In case more specific site information is available the general type can be made more site specific by using the Conceptual Site Model (CSM). Based on the CSM the investigation protocol may be specified to a greater detail, regarding assessment of the contamination levels of the source and the major pathways and receptors of concern.
General notes:

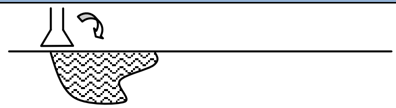
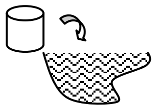
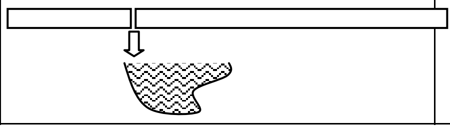
- At one contaminated site more than one type of contamination can occur. For each type of contamination and for each source a separate investigation strategy has to developed first but the investigation activities can be combined to result in an efficient investigation.
- There is always some uncertainty about the representativeness of the samples to actual site conditions due to variation in local conditions which can affect the vertical and lateral distribution of contaminants.
- Composite samples may enable a cost effective investigation of the average concentration levels in contaminated soil or sediment. Composite samples can be made up to a maximum of ten individual samples. The individual samples have to be taken from layers with comparable soil/sediment characteristics. In case individual samples have different olfactory characteristics, they should not be mixed in the composite sample but they should be tested in the laboratory individually. Composite sampling is not applied for groundwater or surface water nor in case of volatile contaminants.

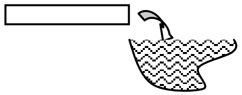
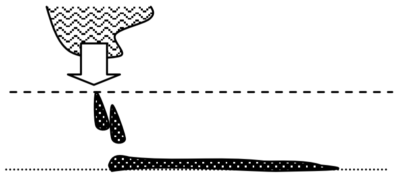
2 Field investigation strategy based on typology

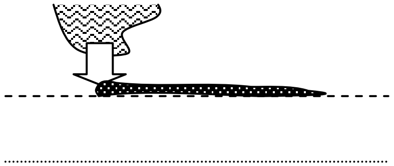
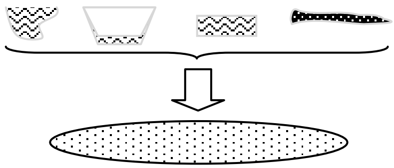
Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
S1	Solid phase contamination (land bound)				
S1-a	Mixing the soil with contaminated material or materials containing contamination, not including agricultural activities.		• May be a thick layer of contaminated material. • Not always visually recognisable (possibly covered with natural soil material). • Relatively heterogeneous composition. • Shape depends on the mixing process.	• If location of source is not known screening methods can be first step for rough indication • If the composition is heterogeneous screening techniques may help to find the most contaminated spots where sampling should be carried out. • If location of source is roughly known sampling of soil and waste material is carried out. • If no spots are identified the samples are evenly distributed over the location of the expected source. This evenly distribution may be influenced by the accessibility of a sampling spot (rather sample of not-covered material in stead of a sample from material below a sealed surface (road, building). • Depth of samples at least to level of contaminated material (based on historical informatial, screening results or visual and olfactory evidence during sampling). • In case different layers of contaminated material within one source are expected for each layer a sample should be	• For non-lineair sources a sampling grid can be used. Rough indication for number of borings from which samples are obtained: 2-4 borings per acre, with a minimum of 2 per source. • Rough indication for number of samples to be tested: 0.25-1 per acre. • For linair sources a cross section of borings is carried out within certain distance intervals. Rough indication of intervals: 1 cross section per 20-50 meters with a minimum of 3 cross sections. Per cross section 3-5 borings and for each cross section 1 sample is obtained. • Composite samples made of a maximum of 10 samples before laboratory testing is possible to get indication of average concentration levels. Composite samples are only allowed for components with immobile and non-volatile character (heavy metals, PCB's, most PAH's and
S1-b	Embankment, filling of pits or depressions, filling of surface waters with contaminated material or materials containing contamination. E.g. a former dumpsite.		• May be a thick layer of contaminated material. • Not always visually recognisable (possibly covered with natural soil material). • Composition may either be homogeneous or heterogeneous. • Shape is determind by former or present topography, lineair as well as non-linair shaped source may occur.		

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
				collected. • In case the source of the contamination is expected at great depth below surface and the contaminants may dissolve relatively easy, a water sample from a groundwater well may be more efficient than sampling of soil at great depth.	pesticides).
S1-c	(Bulk) storage of contaminated material or materials containing contamination (leftovers after having removed the stored materials). (Industrial) activities in which contaminated solids are used. 'Leftovers' of incineration and burning of material. Demolition and construction of contaminant containing constructions (e.g. asbestos).		• Shallow layer of contaminated material. • Material present at the surface and visually recognisable. • Relatively homogeneous composition.	• Same applies as above. • With regard to depth of samples, maximum depth can be 0,5-1 meter depending on expected depth of source.	• Same applies as above. • With regard to number of borings and samples it is possible to use half of the average of borings mentioned above because of the relative homogenity of the material. Do however apply the minimum numbers as mentioned.
S1-d	Adding material containing contamination through agricultural activities (e.g. pesticides, fertilizers or		• Shallow layer of contaminated material. • Material present just below the surface. • Visually not recognisable. • Relatively homogeneous		

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
	additives to animal feed).		composition.		
S1-e	Atmospheric deposition (roads, railway, industries) of emissions or windblown dust.		• Shallow layer of contaminated material. • Material present at the surface. • Visually not well recognisable. • Relatively homogeneous composition.		
S1-f	Deposition by flooding or washing.		• Shallow layer of contaminated material. • Material present at the surface. • Visually sometimes recognisable. • Relatively homogeneous composition.		
	Solid phase contaminations (water bound)				
S2	Contaminated open water sediments.		• The material to be investigated consists of the soil/sediment and parent material beneath the surface water body. • Exact location of the source cannot be identified visually. • Lineair (canals, rivers, creeks) as well as non-lineair (lakes, ponds) shaped sources are common.	• Screening methods are not appropriate. • The site is divided in different investigation areas. Per unit area a number of samples are collected. • Samples are evenly distributed over the area. • Depth of samples is related to depth of the sediment layer. The result of the boring from which samples are obtained may provide a first indication of this depth, although during this step delineation is not primary	• For non-lineair sources a sediment sampling grid can be used. Rough indication of number of investigation unit areas: 0.5-1.5 per square root of the surface area (acre). Rough indication for number of borings: 6 borings per unit area, with a minimum of 2 per source. • Indication for number of samples to be tested: 1 composite sediment sample per unit area, for laboratory testing.

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
				objective. • The effect of contaminated sediment on the surface water quality can be checked by sampling of the surface water (taking into account background quality of the water).	• For linair sources a cross section of borings in the sediment is carried out within certain distance intervals. Rough indication of intervals: 1 cross section per 500-2,500 meters. Per cross section 3-5 borings and for each cross section 1 composite sample for laboratory testing.
	Liquid phase contaminations				
L1-a	(Business) activities involving fluids e.g. solvents, lubricants, paint, etc.		• Sometimes visually or olfactory recognisable point source. • Dispersion in shallow soil layers depends on soil characteristics, possibly at great depth.	• Identify core of the source, visually or olfactory or with help of screening methods. • Samples in the core or very near to the core. • Depth of sample is 0.5 m below level of core (maximum depth for this preliminary site investigation step: 5 meters below surface).	• Number of borings is 2-5 (related to a surface of 250-2,500 acres). • Per core 1 sample of apparently most contaminated material is tested in laboratory. • When olfactory observations indicate presence of contamination in groundwater, 1 groundwater sample per core mus be tested in laboratory.
L1-b	Storage of liquids that contain contaminations in tanks or barrels (either storage on surface or subsurface).		• Often not visually or olfactory recognisable point source because of subsurface release of products. • Dispersion in shallow soil layers depends on soil characteristics, possibly at great depth.		
L1-c	Transfer and transport of fluids through piping. Weak point are		• Often not visually recognisable point source because of subsurface release of products.		

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
	couplings, pressure regulators, valves, breakpoints and the passage through foundations / buildings.		• Dispersion in shallow soil layers depends on soil characteristics, possibly at great depth.		
L1-d	Spills or leaks of liquids. (either on surface or in rivers/lakes) Note. Possibly leading to type S2 or P2.		• Visually well recognisable point source. • Dispersion in soil and sediment as described for Types P2 and S2.		
	Liquid waste related				
P1-a	Dense Non-Aqueous Phase Liquid (DNAPL) in permeable soil. (bulk density > water)		• A liquid that is both denser than water and is immiscible in water or does not dissolve in water. • DNAPLs tend to sink below the water table when spilled in significant quantities and only stop when they reach less impermeable soil layer/impermeable bedrock. Their penetration into an aquifer makes them difficult to locate and remediate.	• Identify core of the source. • Samples in the core or very near in the direction of the groundwaterflow. • Depth of samples is to the level of a less permable layer. The depth of the less permeable layer may be determined using screening investigation techniques. • Visual or olfactory observations of drilled material 0.5 m below level of core (maximum depth for this preliminary site investigation step: 5 meters below surface). • Because of required depth of the samples necessary to investigate DNAPLs this investigation is may be too extensive for the preliminary site investigation. If the site already is regarded as contaminated site it is	• Sampling pattern and number of samples are customized, based on the Conceptual Site Model. • Deploy precautionary measures to prevent or mitigate penetration of less impermeable soil layers.

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
				recommended to investigate during the detailed site investigation.	
P1-b	Light non-aqueous phase liquid (LNAPL) in permeable soil. (bulk density < water)		• Groundwater contaminant that is not soluble and has a lower bulk density than water. • Once LNAPL infiltrates through the soil, it will stop at the water table.	• Identify core of the source. • Samples in the core or very near in the direction of the groundwaterflow. • Depth of boring is 0.5 m below groundwater level and filter of monitoring well has to be placed in such a way that is crosses the LNAPL layer. • In case of deep groundwater levels the necessity of this investigation during this stage of the assessment of the site has to be considered.	• Sampling pattern and number of samples are customized, based on the Conceptual Site Model. • Point of attention: the thickness of LNAPL measured in a monitoring well may be different from the actual LNAPL thinkness in the soil.
	Leached or dissolved contaminants				
P-2	Groundwater contamination due to spreading of leachate or dissolved contaminants in a permeable soil.		• The size, concentration and extension of the contamination are depending on many aspects: the area where the source of the contamination is present (e.g. a large area of the source will result in a large area of the plume), the chemical properties of the components of the	• Based on the field characteristics a hypothesis of the form and extension of the plume of contaminated groundwater is developed and from that a decision can be made how data of the contaminated groundwater should be collected. • Screening techniques may be used or samples can be obtained from e.g. monitoring wells.	• Depending on the form and length of the plume a pattern of groundwater sampling points may be developed. • For point sources with a clear core of the source (maximum surface is 0.25 acre) a number of 1 sample reaches • In case of larger sources of contamination a number of

Type	Activity	Icon with typical field situation (cross-section)	Field characteristics	Field investigation strategy	Indication sampling pattern and number of samples
			contamination (e.g. more mobile components will cause larger volume of the contaminated plume), the geological stratigraphy (e.g. vertical barriers may prevent spreading of groundwater or force it into a certain direction) and soil structure (e.g. high permeability will cause larger volume of the plume), the hydrogeological situation and the period the contamination is already present in the groundwater.	• Monitoring wells can be placed after carrying out borings (by hand) or drillings (motor driven) or using probes equipment.	0.25-1 per acre may be applied. • From each monitoring well a groundwater sample shall be tested in laboratory for the most relevant parameters.

3 Additional points of attention

3.1 Difference between waste and soil

Often samples of soil and sediment have to be taken by drilling through a layer of waste or rubble. If this is the case three issues should be addressed:

- During drilling contaminated material (which may be waste) from upper layers should not be taken into deeper layers;
- After the drilling the borehole has to be sealed properly to prevent future migration of contamination downwards into the borehole;
- In a situation where a protection layer has been applied under a layer of waste material it has to be prevented that this layer will be perforated by the drilling. Either that or it should be restored afterwards.

The fieldwork team is responsible for signalling of the presence of waste or rubble during sampling. An International Standard ISO/CD 25177 Soil quality – Field soil description, is presently under development. In the draft version of this standard a classification of soil layers or horizon aspects is provided. One of the criteria is related to special soil constituents, not being natural sediment like gravel, sand, loam, silt or clay grains, humus or peat (examples: brick, concrete, glass). In case the total volume percentage of these special soil constituents is more than 50% the layer has to be named after the dominating special soil constituent (e.g. brick layer).

During the fieldwork the team involved needs to accurately define the different layers of soil and other substances such as waste or rubble. Observation of the special soil constituents and reporting of it has to be done by fieldwork team.

3.2 Undisturbed sampling

In case it is known that contamination at a site may include volatile substances undisturbed sampling is recommended in order to ensure that substances will not evaporate before laboratory analysis has taken place. This undisturbed sampling can be carried out using thin-walled core samples. However, it is quite costly to sample every layer with thin walled sampling tubes. Therefore, it is suggested, in line with international best practice, that only relevant layers will be sampled using such tubes. If during fieldwork a contaminated layer is encountered (olfactory evidence of volatile material which often appears at or near groundwater level or in a sample with high moisture content) a separate drilling can be carried out next to the first drilling in order to take undisturbed samples using thin walled sampling tubes. For regular drilling and sampling it is recommended to take samples and put them in a jar immediately after excavation. If composite samples are required this should be done in the laboratory instead of composing samples in the field.

3.3 Determination of background values

Often it is important to determine the background values in a certain area in order to make a proper delineation of a contaminated site. These background values may be influenced by anthropogenic sources or may be related to geology of the area.
This determination is always site specific. However, there are some rules of thumb on how to define background values.
At first information from the desk study about the history of the site and its surroundings and information about the cause of the contamination is important to take into account. Maybe information on values of parameters in soil, sediment or groundwater in the area is already available.
If these values are not available samples have to be taken at points which have not been influenced by contamination at the site where the investigation is focussed on. For a first indication of background values at least 3 samples should be taken and testing results compared with those of the samples of the contaminated site.

In case of substantial consequences for investigation and remediation it may be important to provide a statistically underpinned background value. This may be applied during the detailed site investigation because of the efforts involved. In such a situation it is required to set up a database based on which statistical analysis can be made. This involves the following steps:

- determine for which area (with single item soil structure and use) the value will apply;
- make use of a suitable data set (sufficient quality (criteria), good spatial distribution across the area);
- remove extreme values and point source locations from the dataset that differ from the general area quality;
- complete the dataset if at parts of the area are not enough samples are available, there should be at least 20 samples per area;
- determine average, confidence interval and P80, P90 and P95-values;
- compare the values at the site with the applicable P-value.

Volume III

2.2-iii Overview of techniques for site investigation

Volume III-2.2-iii
Overview of techniques for site investigation

1 Introduction

This Section is most relevant for Task 2.2, Preliminary site investigation, and Task 5.1, Detailed site investigation.

This Section provides a first overview of techniques, which are widely used. Screening techniques (Section 2) as well as sampling collection techniques (Section 3) are described.
For more detailed information on sample collection, extraction and testing site investigation tools the user may refer to more detailed data such as:

- Field Sampling and Analysis Technologies Matrix and Reference Guide, Prepared by the Naval Facilities Engineering Command and the U.S. Environmental Protection Agency: http://www.frtr.gov/site/toc.html
- Dutch directive on restoration and management of soil, groundwater and sediment, provides information on 130 techniques for investigation: http://www.bodemrichtlijn.nl/Tools/bodemonderzoekstechnieken/applicatie-zoeken-naar-onderzoekstechnieken (English translation is provided on this internet page)

Depending on the situation the field investigation team must use personnel protection equipment. Basic equipment includes: boots, protective clothing, dust masks, goggles or safety glasses and gloves.

2 Technical screening equipment

This Section shows an overview of technical screening equipment for preliminary site investigation (see table III-2.2-iii-1). These techniques are typically used in a first step in a Preliminary site investigation, in cases where the location of the source or the pathway or both is not known. These techniques provide a *'quick and dirty'* approach to assess a rough delineation of the source or pathway or both, needed to make a next step in the preliminary site investigation, which involves sampling and testing.

The table is to be used as a first overview to all techniques. For more detailed information on sample collection, extraction and testing site investigation tools reference may be made to the above mentioned websites.

Some of the techniques show accurate on site contaminant concentration levels. The techniques are described for typical situations based on best practices and expert judgment.

The selection of techniques should be well considered to avoid inefficiency. For example, seismic methods can be used to determine the groundwater table. This information is regarded as 'secondary data' gained from this technique as the technique is primarily used for stratigraphy assessment. Therefore, if only the groundwater table has to be measured seismic techniques are not recommended.

Some techniques are indicated to be able to measure contaminations. Depending on the technique this can be either quantitatively of qualitatively. The XRF for instance is able to provide parameter specific ppm data while magnetic field methods will provide quantitative spatial information, e.g. the outlines of a dump site. The latter techniques provide the opportunity to distinguish between pristine soil layers and layers possibly contaminated.

Table III-2.2-iii-1 only shows categories of techniques. A wide variety of subtechniques is available. These techniques either are commercially linked to one specific supplier or are generic techniques available, regardless of the supplier (e.g. auger sampler or cone penetration test).

For each technique spatial representation is indicated with 'point/line/3D', indicating if data is collected on a discrete point, along a vertical or horizontal line or gives a 3D image of the matrix. Some notes should be made to this point:

- Multiple points can build up to line data and multiple lines can build up to a 3D image;
- Some techniques may give point information but the data generated may represent a large volume of soil, sediment or air. For example, a gas detection reading is based on a volume of air which is pumped through the tube. The spatial representation of this measurement depends on the volume of air and area where it is extracted from.

Table III-2.2-iii-1: preliminary site investigation survey techniques for quick screening of sites: basic characteristics and typical application

	Electro magnetic methods	Geo-electric and Self Potential methods	Magnetic field measurement	Ground penetrating radar (GPR)	Radiometric measurement	Seismics (sonar)	Penetration test cones	XRF X-Ray Fluorescence	NIR Near IR luminescence	PID Photo-Ionisation Detector	Gas detection tubes
Basic characteristics											
Parameter	Electrical soil resistivity	Electrical soil resistivity	Magnetic susceptibility	Dielectric constant	Gamma ray radiation	Acoustic impedance	Various	Concentration (heavy metals)	Concentration (heavy metals / some organic compounds)	Concentration of contaminations in the air	Concentration (parameter sensitive reagent)
Unit	Ω/m	Ω/m	Gauss	F/m	Bequerel	ms or kgm^2	Various	ppm	ppm	ppm	ppm
Property of investigation	Electro magnetic induction	Galvanic resistivity	Magnetic field	Reflection/refraction electro-magnetic field	Radio active radiation	Reflection/refraction of sound waves	Various	wavelengths of the emitted X-Rays	Near IR luminescence	Ionisation of charged molecules	Speed of chemical reaction
Typical field specification											
Range of depth	0 – 25 m	0 – 100 m	0 – 10	0 – 25	0.1 m (in situ) > 0.1 m (samples)	1 – 100 m	0 – 50 m	0.1 m (in situ) > 0.1 m (samples)	0.1 m (in situ) > 0.1 m (samples)	NA > 0.1 m (samples)	NA > 0.1 m (samples)
Soil/water/air/ sediment	Soil/sediment	Soil	Soil/sediment	Soil	Soil/water/air/ sediment	Soil/sediment	Soil/sediment	Soil/water/air/ sediment	Soil/sediment	Air (sample)	Air (sample)
Resolution	1 – 25 m	1 – 100 m	1 – 5 m	0.5 – 2.5 m	0.1 m	0.5 – 5 m	0.1 m	0.1 m	0.1 m	1 m	1 m
Point/line/3D	point	point	point	line	point	line/3D	line (vertical)	point	point	point	point
Survey type (Survey technique is (+) highly suitable; (0) suitable with restrictions; (-) not suitable)											
Stratigraphy	+	+	0	+	0	+	+	-	-	-	-
Contamination	+	+	0	0	+	-	+	+	+	+	+
Objects	0	-	+	+	-	0	0	-	-	-	-
Groundwater level	0	0	-	+	-	+	+	-	-	-	-

	Electro magnetic methods	Geo-electric and Self Potential methods	Magnetic field measurement	Ground penetrating radar (GPR)	Radiometric measurement	Seismics (sonar)	Penetration test cones	XRF X-Ray Fluorescence	NIR Near IR luminescence	PID Photo-Ionisation Detector	Gas detection tubes
Practical aspects											
Field personnel (# of field operators)											
	1-2	1-2	1	1	1	>2	1	1	1	1	1
Investigation time needed ((+) quick survey technique; (0) moderate time consuming technique; (-)time consuming survey technique)											
	+	0	+	+	+	-	0	+	0	+	+
Costs (Survey technique is (+) expensive; (0) moderately expensive; (-) low cost)											
	+	0	+	+	+	-	0	+	+	+	+
Much used (Survey technique is (+) used on daily basis; (0) now and then used; (-) seldom used)											
	+	+	0	+	+	-	+	+	-	+	+
Typical type of field survey	Groundwater plume and source recon-naissance / delineation	Groundwater plume and source recon-naissance / delineation	Source and object (drums) reconnaissan-ce / delineation	Stratigraphy, source and object recon-naissance / delineation	Source recon-naissance / delineation	Stratigraphy	Stratigraphy and plume re-connaissance / delineation	Source recon-naissance / delineation	Source and pathway recon-naissance / delineation	Source and pathway recon-naissance / delineation	Source and pathway recon-naissance / delineation

Pictures of some of the screening techniques described in Table III-2.2-iii.1

Figure III-2.2-iii.1a and 1b: Example of Ground Penetrating Radar

Figure III-2.2-iii.2: Example of PID Photo-Ionisation Detector

Figure III-2.2-iii.3: Example of XRF X-Ray Fluorescence

3. Sampling techniques

3.1 Soil sampling collection tools

For the sampling of soil material different types of drills can be used depending on the soil type and type and level of contaminating substances. Some widely used types of drills are described below:

- Hand held techniques:
  - Scoops, spoons, and shovels
  - Augers
  - Tube
  - Gouge
  - Thin-walled core samplers
  - Hand pulse

- Power driven drill techniques
  - Screw drilling system: hollow auger drill
  - Screw drilling system: auger drill
  - Displacement drilling system
  - Cased auger/pulse drill

<u>Hand held techniques</u>

Scoops, spoons, and shovels
Hand-held scoops (10- to 100-gram capacity), spoons (typically 300- to 2,000-gram capacity), and shovels are used for exploratory holes, test pits and sampling near surface soils.
Accurate, representative samples can be collected depending on the care and precision demonstrated by the sample team member. The use of a flat, pointed mason trowel to cut a block of the desired soil can be helpful when undisturbed profiles are required. Care should be exercised to avoid use of devices plated with chrome or other materials. Volatiles may be lost during sample collection.

Figure III-2.2-iii.4a Example of soil sampling with shovel

Figure III-2.2-iii.4b Example of trial pit excavated with shovel

Augers

Augers are commonly used to collect near surface samples and, in combination with tube samplers, to collect undisturbed samples. Examples of augers: Edelman-drill, “riverside” drill, gravel drill.

This auger is used for drilling up boreholes to the groundwater level. It can also be used in cohesive soils. Smearing can be prevented by using an increasingly smaller diameter or by using a (lost) casing. The “riverside” and gravel drill have more disturbed samples than the Edelman-drill, but samples never cover more than 10 to 15 cm in height.

Figure III-2.2-iii.5a Example of augers (left) and handles (right)

Figure III-2.2-iii.5b Example of augers. From left to right: Riverside (gravel, debris), auger (sand), Edelman auger

Figure III-2.2-iii.5c and 5d: Examples of soil sampling with Edelman auger

Tube

Tube drills are used in (relatively) cohesive soils to obtain almost undisturbed samples. They provide fast and simple information on the (shallow) soil structure. Samples have a small volume but are useful for profile descriptions. The maximum reach depth is between 5 and 10 m below ground surface level. Like augers, tubes can utilize a variety of tips depending on soil type. Tubes are considered better than augers for sampling VOCs. Tubes are similar to augers except that a tube with a cutting tip is attached to the drill rod. Instead of being rotated, the tube is pushed into the soil.

Often augers are used to drill the hole and tubes are used to collect the sample. Tubes are not suitable for rocky, dry, loose, or granular material or very wet soil. A variety of tube samplers are available. Some tubes can be driven into the soil by a demolition hammer. This system is often used when debris in the subsurface occurs. There are also fully closed tubes/gouges with liners or with a foil in which the sample is entered.

Figure III-2.2-iii.1. Example of soil sampling with tube

Gouge

Similarly to tubes, gouge drills are used to collect undisturbed samples generally from soft and wet soils. Gouges are long, semi cylindrical chambers made of tapered stainless steel, that are pushed into the soil, twisted and recovered to display a full profile of the soil. Gouges are usually used to collect small samples, e.g. to determine soil water content by mass.

Figure III-2.2-iii.2 Example of soil sampling using gouge

Thin-walled core samplers

Thin-walled core samplers are most commonly used for collection of undisturbed core samples in cohesive soils, silt, and sand above the water table. Sample collection procedures are similar to split-spoon sampling except that the tube is pushed into the soil, using the weight of the drill rig, rather than driven (Shelby tube or Continuous tube).

Figure III-2.2-i.3a Examples of thin-walled core samplers

Figure III-2.2-iii.8b Example of sampling with thin-walled core samplers

To avoid volatile components to disappear from the soil samples after excavation a method has been developed to prevent this evaporation. A small tube is filled with soil material and methanol is added in the same amount.

Figure III-2.2-iii.8c and 8d Illustration of adding methanol to soil sampling material

Hand pulse

The hand pulse drill is used in non- or little-cohesive soils, below the water table. The borehole will be protected against collapsing by a casing made of steel or plastic. The soil material just below the casing is loosened with the help of the pulse and removed. Mechanical pulse installations are used for drilling from 10 m below ground surface level. When a hard clay layer or a strongly contaminated zone (for example a layer of purely contaminated substance) is penetrated, an additional casing with a smaller diameter is used.

Figure III-2.2-iii.9a Example of hand pulsing, using tripod and steel casing

Figure III-2.2-iii.9b Example of hand pulsing

Power driven drill techniques

Screw drilling system: hollow auger drill

Consists of a hollow central shaft with a removable sheet or valve structure at the bottom end. Due to the unfavorable spiral width diameter ratio the soil material is strongly displaced and hard to interpret, because it is smeared. Two types of hollow auger drills: in the simple system the soil is sampled without disturbing it parallelly, and in the more complex system a non-rotating sampling tube is pressed down and collects the sample in the hollow central part, while the surrounding soil is being drilled up through the space surrounding the central part.

Figure III-2.2-iii 4. Hollow auger drill

Screw drilling system: auger drill

With an auger, cohesive soils can be drilled up to 30 m below ground surface level above the water table. The jacked ground is mixed, which increases with depth. Indicative sampling or profile description is only possible when the drill is screwed into the soil like a corkscrew (lowering speed is equal to the rate of the windings) and then not turned when it is pulled up.

Figure III-2.2-iii.11a Auger drill

Figure III-2.2-iii.11b Machine driven auger drill

Displacement drilling system
There are two ways to take samples with this method. First method is a relatively thin tube provided with a lost point that is pressed into the soil to the desired depth. Inside this tube a very thin monitoring well is lowered. Then the casing is pulled up after which the filter remains. Second method is a sounding tube with an integrated filter that is pressed down until the desired depth is reached. Then the groundwater samples are taken immediately.

Figure III-2.2-iii.12a and 12b: Examples of power driven displacement drilling system

Figure III-2.2-iii.12c and 12d: Examples of sonic displacement drilling system

Cased auger/pulse drill

The auger is used to drill to the wet sand layer. With contaminated soil the casing can be inserted through rotation to limit smearing when it is pulled up. After this it can be pulsed. Within or below the casing samples may be taken. In this method, there is a minimum of smearing and wells with a large diameter are applied.

Figure III-2.2-iii.13a, 13b and 13c: Examples of cased auger/pulse drill

In case of rock or paving, material has to be crushed when drilling bore holes, special equipment has to be used.

Figure III-2.2-iii.13d-h: Examples of cased auger/pulse drill required for Hard ground and rock drilling

3.2 Groundwater sampling collection tools

Groundwater samples can be collected through several types of pumps depending on the groundwater level, the sampling of volatile compounds, etc.

The following widely used types of pumps are described below as well as filtering of groundwater samples is described:

- suction lift pump
- pressure pump
- bailer sampler
- ball valve pump

Suction lift pump

These peristaltic pumps are frequently used for shallow ground water sampling. Suction lift pumps apply a vacuum to either the well casing or to tubing that runs from the pump to the desired sampling depth. Most are easily controlled to provide continuous and variable flow rate. Peristaltic pumps utilize a self priming or power operated vacuum pump. This pump can be used to a maximum groundwater level of 9,5 m below ground surface level. It can be used for the sampling of groundwater for chemical testing of volatile compounds, provided the suction height is not over 6 m.
For each sample a disposable filter should be used. Filtering the water before bringing it into the sampling bottle is required.

Figure III-2.2-iii.14. Suction lift pump

Pressure pump
This pump, also known as Submersible centrifugal pump, is used for well purging and ground water sample collection. This pump is universally applicable for sampling for chemical testing of volatile compounds, provided the speed of the pump is variable to sampling rate. Submersible centrifugal pumps use an electrically-driven rotating impeller that accelerates inside the pump body, building up pressure and forcing the sample up the discharge line. Commonly constructed of stainless steel, teflon, rubber, and brass, most can also provide a continuous and variable flow rate. Small diameter submersible centrifugal pumps are available that can be used in 2-inch diameter wells and can be operated at both high flow rates for purging and low flow rates for sampling. Maximum depth for sampling is about 70 m below ground surface level. The risk of contamination is very large, so much attention should be paid to the materials and the cleaning of the pump.


Figure III-2.2-iii.15a and 15b: Examples of pressure pump

Bailer sampler
Bailer samplers are the most widely used sampling method, due to their low cost. However, other devices like bladder, helical-rotor, and gear pumps generally provide better results when sensitive constituents such as VOCs are present. A bailer is a hollow tube with a check valve at the base (open bailer) or a double valve (point source bailer). The bailer is attached to a line (generally either a polypropylene or nylon rope, or stainless steel or Teflon coated wire) and lowered into the water. The bailer is pulled up when the desired depth is reached, with the weight of the water closing the check valve. Open bailers provide an integrated sample of the water column. Point source bailers use: (1) balls or (2) valves (operated by cables from the surface) to prevent additional water from entering the bailer so that a sample can be collected at a specific point. Maximum depth for sampling is about 70 m below ground surface level.

Ball valve pump

The ball valve pump is used to push water upward. The pump is connected to the end of a sampling hose or tube. By moving the tube and pump down, the ball is moving up and it will let water enter into the tube. By pushing the tube and pump up, the ball is closing, so the water goes up with the tube and pump. The moving can be done by hand or by a machine. It uses the gravity and slowness of the mass of the water column. The ball valve pump is available in different diameters for different tube sizes. The pump is small, relatively cheap and it can be used to clean a monitoring well by pumping water and sediment after placement, as well as for sampling monitoring wells.

Figure III-2.2-iii.16a and 16b: Examples of ball valve pump

Filtering of groundwater samples
If testing of a groundwater sample on heavy metals is required, the turbidity in the sample should be as low as possible. Therefore, the sampled groundwater needs to be filtered through a 0,45 µm filter to remove the sediment that causes the turbidity. There are two types of filters for this:

- Filtering by “in line” filtration: the disposable filter is placed directly in between the monitoring well and the sampling bottle. The filter can also be placed at the end of the discharge of a anaerobic acting pump like a peristaltic pump (e.g. ball valve pump). The materials that have contact with the sample should be made from physically and chemically inert material. For every well a new filter must be used.
- Filter machine for pressure filtration under a vacuous gas: this machine should be completely removable to clean it. In case it is expected that the filter clogged because of the presence of floating materials, a double filter is used. In the first filter holder the prefilter is placed. This method requires use of gas tanks, quite a lot of detergent and demineralised water to clean the filter holders in between the sampling of different wells. It also requires more skills from the person executing the sampling and filtering, compared to the filtering process described above.

Figure III-2.2-iii.17a and 17b: Examples of filtering groundwater samples

3.3 Sediment sampling collection tools

For the sampling of sediment material different types of drills can be used. Some widely used types of drills are described below:

- Piston drill
- Sediment core-sampler
- Grabbers

Piston drill

The piston consists of drilling a through tube, normally made of stainless steel, to which extension rods can be attached. The insert tube is pressed into the sediment with the rod system, while the piston is kept at a constant depth with respect to the sediment. This piston maintains a negative pressure, causing the sample over the full cutting depth to be recorded into the penetration tube. The maximum cutting depth of the piston sampler is 2 m. There is no visual inspection if the sample also includes the upper surface. Coarse sand or very watery material drops during the acceleration of the piston bore. There is no provision, other than the vacuum of the piston, to keep it down in the tube.

Figure III-2.2-iii.18: Transparent material piston drill

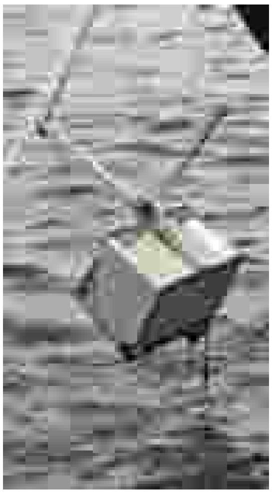
Sediment core sampler

The sediment core sampler (in this case of the so called Beeker type) consists of a cutting head with an attached transparent penetration tube of polyvinyl chloride, which is presses or hammers the extension rods into the soil. A piston down tube creates a vacuum, which enables sampling of the best stitch length down tube (sample tube). Once the penetration tube arrives at the correct depth, a rubber bellow can be inflated in the cutting head so that the bottom of the sample tube can be closed. The sampling unit can then be retrieved. Subsequently, the sample can be judged visually and expressed in sample pots or a gutter. The maximum stitch length of a Beeker sediment plug is 2 m, with a diameter of 63 mm. In stagnant water it can be applied to 10 m depth.

Figure III-2.2-iii.19 Example of sediment core sampler

Grabbers
The so called Van Veen grabber, the example of a grabber described here, is a grabber with a cable or rope lowered to the bottom. When hitting the bottom of the suspension cable an unlocking mechanism is set into motion. By subsequently pulling up the cable the sample is snapped out of the sediment. The device collapses weak sludges, and collects, depending on the size, only a shallow sample. It can be applied in non or hardly flowing water to all depths.

Figure III-2.2-iii.20a and 20b: Examples of grabbers

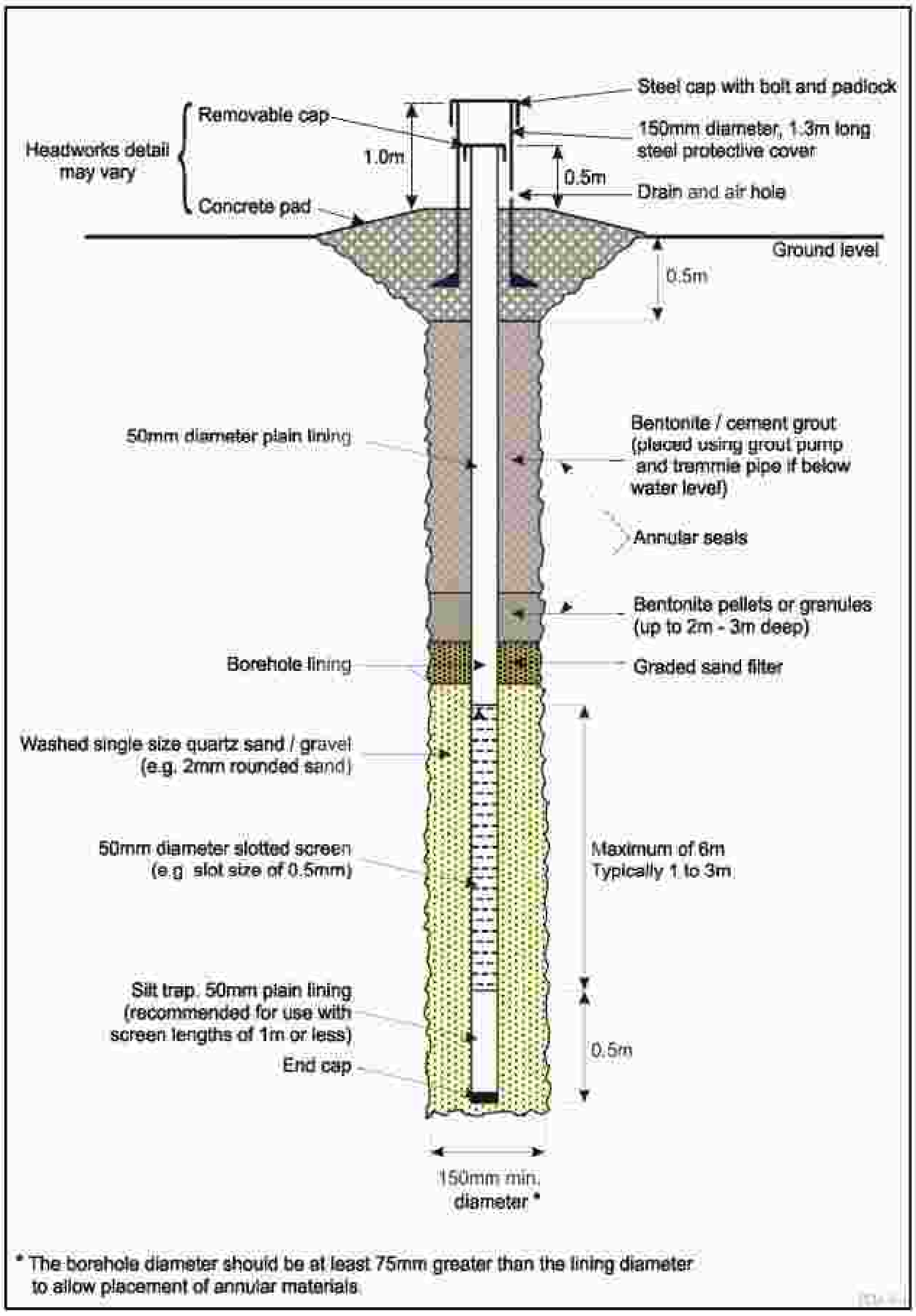


3.4 Other materials required for drilling and sampling

Piezometers and monitoring wells

For measuring groundwater level and for sampling groundwater monitoring well pipes may be installed in boreholes to create piezometers and monitoring wells. These pipes are normally made of plastic which is inert and does not influence the quality of the groundwater. The pipes have slits through which the groundwater can flow into the pipe where it is extracted for sampling. After installing the pipe a cap with lock should be applied to be able to prevent disturbance of the wells.

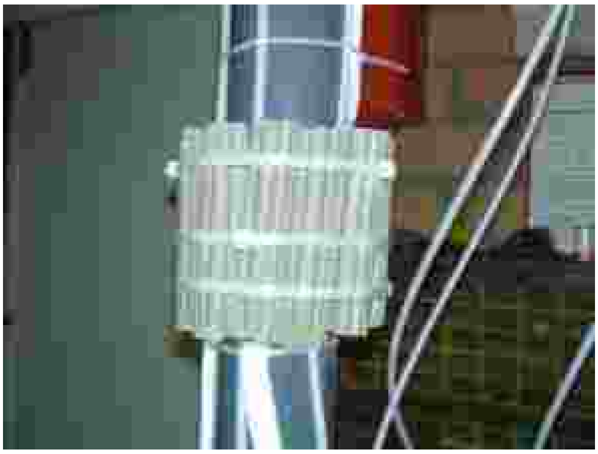
Figure III-2.2-iii.21: Example of generic groundwater well design



Swelling clay
Groundwater may be differentiated by the stratigraphic layers in soil. Drilling can cause leakages between these layers which may lead to unintentional intrusion of contaminated substances into a layer of fresh and undisturbed groundwater. To prevent groundwater flow between different soil layers swelling clay must always be used. This clay can be added as pellets or as plugs, as shown in the figures III-2.2-iii.22 a and b respectively.

Figure III-2.2-iii.22a: Bentonite pellets

Figure III-2.2-iii.22b: Bentonite plug



Filter sand or gravel
After drilling a borehole a monitoring filter may be placed in the hole. For the filling of the space between the filter and the borehole sand or gravel should be applied, at least for the length of the filter, to enable groundwater flow through the filter. Filter sand is not required in case of very coarse and well drained soil layers. Examples of filter sand are shown in figures III-2.2-a and b.

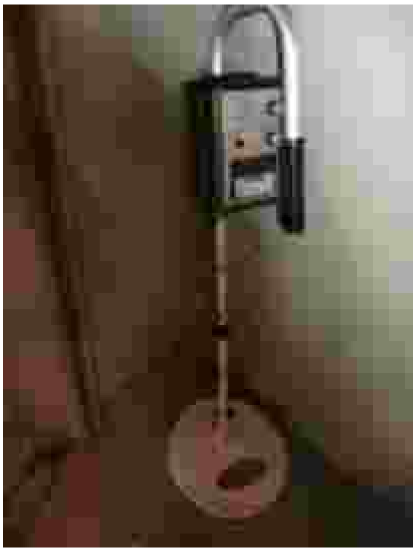
Figure III-2.2-iii.23a and 23b: Filter sand

Groundwater level measuring device
Many tools are available to detect the groundwater level in a monitoring well. Some of these are illustrated in figure III-2.2-iii.24a-d below.

Figure III-2.2-iii.24a-d: Examples of groundwater level measuring tools

Metal detector
A metal detector may be used to detect the presence of hidden objects of metallic origin below the surface, such as tanks, barrels and cables. In case such objects are expected at a site it should be considered to excavate a hole by hand before performing mechanical drilling.

Figure III-2.2-iii.25 Example of metal detector



Oil water observation tool
To detect if there are floating contaminating compounds in soil or groundwater a tool may be used for rapid on site observation. This tool does not provide information on the exact substances and concentrations.

Figure III-2.2-iii.26a and 26b: Examples of oil-water observation tool / oil detection pan

Sediment level measuring device
A method to roughly assess the thickness of a sediment layer is to use a hand held tool, as illustrated in figure III-2.2-iii.25a and b below.

Figure III-2.2-iii.27a and 27b: Example of tool to detect sediment level

Samples coolers
Laboratories provide information about maximum holding time for samples before analysis is carried out. Samples of contaminated material should, as much as possible, be kept under conditions which will not influence the contaminants before arriving at the testing laboratory. Often, this involves cooling, especially when samples are to be tested for volatile compounds.

Figure III-2.2-iii.28a and 28b: Examples of sample cooling methods

Volume III

5.1-i Example investigation strategy detailed site investigation

Volume III-5.1-i
Example investigation strategy detailed site investigation

1 Introduction

This information is most relevant for Task 5.1 Detailed site investigation.
A detailed site investigation is always a site specific exercise for which a site specific investigation protocol should be developed. An example of the development of an investigation strategy is provided below.

2 Example investigation strategy detailed site investigation

The following example explains how an investigation strategy should be tailor made to specific situations. The examples refer to a situation of a contaminated top layer (S-1 type: solid phase contamination, land bound site) caused by elevating the ground level by using contaminated material and mixing it with the soil underneath.

Available project information
Site inspection provided information that the contaminated top layer occurs to a depth of approximately 0.8 m. The groundwater is about 1.5 meters below ground. The area is approximately 3000 m². The concentrations of copper, lead, zinc and PAHs in the top layer are in excess of the Response levels. From the results of the analysis of the groundwater it concludes that the contamination is immobile: no relevant groundwater contamination was found. Future use of the site is residential.

Define scope
In respect to the sensitive future land use remediation of all contaminated material at the site is considered. The remediation may be carried out by removing the contaminated top layer and replace it by a clean soil layer of about 1 m.

Establish required information
Based on the scope of the investigation of the investigation the required information is established. In this case the sort of information that has to be collected and the required level of detail of this information, is closely dependent on the remediation option to be carried out. The information to be collected is required in order to:
- delineate the contaminations because it is expected that the contaminated material will be fully removed;
- determine the treatment possibilities of the contaminated material representative levels of contaminants including organic matter and clay content, and quantities of debris and large waste particles;
- determine the remediation costs.

The required level of detail for the investigation is determined by what is sufficient enough to determine the depth of the contaminated material. The level of detail required is determined per soil layer as follows:

- 0.0 to approximately 0.8 m below: to be excavated;
- approximately 0.8 to approximately 1.3 m below: vertical demarcation size determination.

Developing a conceptual site model (CSM) of the situation
Based on the available data, a conceptual site model is developed, in which particular attention is being paid to [i] the data that has to be collected and [ii] the possible remediation option which will likely to be executed.

Conceptual model in table

Situation of the contaminated multiplication layer:	The site is part of the larger area where these kind of contaminated layers are expected. At the location the multiplication layer extends to 0.8 meters depth. Within the boundaries of the location the intention is to fully remove the contamination.
Groundwater quality and household:	Not significantly contaminated groundwater, groundwater level is at a depth of 1.5 m below ground level.
Possible remediation variant:	Soil top layer may be completely excavated down to 0.8 meters below ground level. The excavated area will be supplemented with clean soil.
Party-division and size:	from 0 to 0.4 m depth: about 120 m^3 polluted ground, including asbestos and admixtures of debris from 0.4 to 0.8 m depth: 120 m^3 contaminated soil, asbestos is not suspected, soil admixtures of foreign material. Volume weight is unknown so the calculation from m^3 to tons is uncertain, which determines the remediation costs.
Treatment possibilities material:	Transport and disposal or sifting of debris and extractive cleaning, representative concentrations of contaminants and other relevant parameters (humus, clay, grading curve) for treatment possibilities of both parties are lacking. It is unclear if the soil underneath the contaminated layer has been contaminated by leaching as well.
Risks of working with contaminated ground:	PAHs, lead and asbestos is present, representative concentrations and soil moisture content is not known.

Note: the above conceptual model is later included in the report of the detailed site investigation. In the conclusion of the report it is addressed in particular the investigation questions that were answered during the investigation.

Formulation of specific required information:

- What is the average concentration of the expected chemical substances, clay content, organic matter in the layer of approximately 0.0 to 0.8 meters deep? What is the grain-size distribution of the soil particles?
- What is the average concentration of chemical substances in the layer of approximately 0.8 to 1.3 meters deep?
- What is the required excavation depth?
- What is the volume weight of both to be discharged parties?
- What is the percentage of the debris and large waste particles in the top layer?

Investigation protocol

- Inspection holes or test pits should be excavated in the top layer. Visual inspection of the surface and the excavated material is important. Samples will be taken from the individual recognizable layers.
- The inspection holes are spatially distributed in the backyard: 5 inspection holes dug from 0.3 to 0.3 meters wide and 0.5 meters deep. All inspection holes are 12 cm by hand drill put to approximately 1.3 meters.

When the soil is sampled, a distinction is made in the following two layers in below table:

Layer	Sampling contaminated material	Sampling volume weight
Toplayer	*per test pit / drilling 1 sample-pot, dilution processes at laboratory*	*1 undisturbed sample using tube*
Non-suspected subsurface layer below top layer	*Per drilling one sample-pot, dilution processes at laboratory*	*None*

Volume III
5.2-i Tools for risk assessment

Volume III-5.2-i
Tools for risk assessment

1 Introduction

This information is most relevant for Task 5.2, Risk Assessment. During the risk assessment tools may be used to support the qualitative or quantitative assessment. First, the use of a diagram to establish the relevant exposure routes is explained. Subsequently, information is provided on the internationally favoured risk assessment models.

2 Diagram for establishment of exposure routes

A diagram (refer Figure III-5.2-i.1) may be used to illustrate how exposure routes depend on source, land use and detailed site establishment. This is the qualitative phase in the risk assessment process, as described in Volume I under Activity 2. In the quantitative phase of the risk assessment process (as described in Volume I under Activity 3 and 4) attention should be paid only to the identified potential exposure routes, which are shown in the diagram.

An indication of the exposure routes relevant for a specific site can be established by applying the following steps:

1) Identify the contaminants of concern in the source. This information is obtained from the previous Tasks 2.2, Preliminary site investigation, and 5.1, Detailed site investigation;
2) Determine the pathways through which the contaminants are migrating to the possible receptors. More detailed information on the pathways is provided in Box III.5.2.1 below;
3) Indicate land use (on-site and off-site). Generic forms of land use are mentioned in Box III.5.2.2 below;
4) In addition to these generic forms of land use information on the detailed situation at the contaminated site should be collected. This can be done for example from a plan, from a map or from interviews with local people. Examples are provided in Box III.5.2.2 below;
5) Identify the receptors currently or potentially exposed to site contaminants. This includes humans and other organisms that are in direct contact with the source of contamination, or are potentially present along the migration pathways, or are located in the vicinity of the site. Maps indicating the contaminated sources, pathways and receptors may support the identification. For ecological receptors terrestrial and aquatic habitats for plants and animals within and around the study area or associated with the source(s) or migration pathways are important to identify.

Box III.5.2.1 Identification of pathways (exposure routes)

Potential migration pathways by which contaminants are migrating through groundwater, surface water, air, soils, sediments, and biota should be identified for each source. Based on the ASTM-1689 guideline for Conceptual Site Models the following pathways are mentioned that may be involved:

Ground Water Pathway:
This pathway should be considered when hazardous solids or liquids have or may have come into contact with the surface or subsurface soil or rock. The following should be considered further in that case:

- vertical distance to the saturated zone;
- movement through the unsaturated zone;
- subsurface ow rates;
- presence and proximity of downgradient seeps, springs, or caves;
- fractures or other preferred ow paths;
- artesian conditions;
- presence of wells, especially those for irrigation or drinking water; and
- in general, the underlying geology and hydrology of the site. Other fate and transport phenomena that should be considered include hydrodynamic dispersion, interphase transfers of contaminants, and retardation.

Surface Water and Sediment Pathway:
This pathway should always be investigated in the following situations:

- A water body (river, lake, continuous stream, drainage ditch, etc.) is in direct contact with, or is potentially contaminated by a source or contaminated area,
- an uninterrupted pathway exists from a source or contaminated area to the surface water,
- sampling and analysis of the surface water body or sediments indicate contaminant concentrations substantially above background,
- contaminated groundwater or surface water runoff is known or suspected to discharge to a surface water body, and
- under arid conditions in which ephemeral drainage may convey contaminants to downstream points of exposure.

Air Pathway:
Contaminant transport through the air pathway should be evaluated for contaminants in the surface soil, subsurface soil, surface water, or other media capable of releasing gasses or particulate matter to the air. The migration of contaminants from air to other environmental compartments should be considered, for example, deposition of particulates resulting from incineration onto surface waters and soil or from dust due to wind over dry surfaces.

Soil Contact Pathway:
Contaminated soils that may come into direct contact with human or ecological receptors should be investigated. This includes direct contact with chemicals through dermal absorption. There is a potential for human and ecological receptors to be exposed to contaminants at different soil depths (for example, humans may be exposed to only surface and subsurface soils, whereas plants and animals may encounter contaminants that are buried more deeply).

Biotic Pathway:
Bioconcentration and bioaccumulation in organisms and the resulting potential for transfer and biomagni cation along food chains and environmental transport by animal movements should be considered. For example, many organic, lipophilic contaminants found in soils or sediments can bioaccumulate and bioconcentrate in organisms such as plankton, worms, or herbivores and biomagnify in organisms such as carnivorous sh and mammals or birds. The movement of contaminated biota can transport contaminants.

Examples of source-pathway-receptor combinations are presented in the 'Diagram for identification exposure routes'.

Box III.5.2.2 Land use and detailed site establishment

The following generic forms of land use can be distinguished:

- Agricultural land;
- Kitchen gardens;
- Forests and other natural area;
- Habitation settlement/residential or school or playground or garden/park;
- Commercial;
- Industrial;
- Infrastructure (roads, parking, railway, subsurface cables and pipes);
- Waste land;
- Water bodies;
- Mixed land use (to be specified for each case);
- Other land use (to be specified for each case).

In addition to these generic forms of land use examples of additional information on the detailed establishment of the contaminated site are:

- are there buildings / houses at the site? At which location exactly?
- are there roads, paths, parking? Which is the material of the pavement?
- are there consumption crops grown?
- is groundwater abstracted for drinking water or other purposes?
- is surface water used for fishery?
- Is access to the site restricted, e.g. a secured industrial site which is accessible only by industrial workers?

Figure III-5.2-i.1: Diagram for identification exposure routes, filled in as an example

Diagram for identification exposure routes

			land use										detailed site establishment								exposure routes and receptors					
													not-sensitive				sensitive				human					eco
	source contamination	pathway		Agriculture land	Kitchen garden	Forests and other natural area	Habitation settlement/Residential	School or Playground or recreational park	Commercial	Industrial	Infrastructure (e.g. roads, parking, railway)	Water bodies	Mixed and other land use	contamination sealed by buildings	contamination sealed by pavement	contamination sealed with clean soil	contamination sealed by other material	water used for fishery	ground water abstracted for drinking water	crops grown	contamination in top layer, not sealed	direct contact	ingestion of crops	ingestion of fish	ingestion of drinking water	inhalation of indoor air	exposure ecology
		soil																									
		groundwater																									
		surface water & sediment																									
		air																									
		biotic																									
example 1	heavy metals	soil	X				X														X	X					
		groundwater	X																X						X		
		surface water & sediment	X																								
		air	X																			X					
		biotic	X																								
example 2	volatile aromatics	soil																									
		groundwater	X				X				X			X	X											X	
		surface water & sediment																									
		air																									
		biotic																									

3 Risk assessment models

Internationally, a multitude of models for the quantitative assessment of risks for human health and water resources is in use. Examples of the most widely used of these models are presented in this Section.

Most of the approaches to risk assessment promote increasing (or tiered) levels of investigation, separated by decision steps. These steps evaluate the need for further investigation regarding the costs of remediation, the assessed risks to human health or to the environment, the costs of further investigation, and the regulatory obligations.

For the derivation of critical exposure values a threshold approach or a non-threshold approach is applied. Threshold effects are assumed to exist for all toxic effects except genotoxicity (direct effect on DNA, which is linked to carcenogenity). In the threshold approach the Tolerable Daily Intake (TDI, see Box III.5.2.3 below) is used.

Box III.5.2.3 Tolerable Daily Intake (TDI)

A TDI is an estimate of the amount of a substance in air, food or drinking water which represents the daily intake over a lifetime without appreciable health risk. TDIs are based on laboratory toxicity data to which uncertainty factors are applied.

For most kinds of toxicity, it is generally believed that there is a dose below which no adverse effect will occur. For chemicals that give rise to such toxic effects, a tolerable daily intake (TDI) should be derived as follows, using the most sensitive endpoint in the most relevant study, preferably in drinking water:

TDI = (NOAEL or LOAEL) / UF

Where:
NOAEL = no-observed-adverse-effect-level, which represents the highest tested dose or concentration of a substance at which no adverse effects is found in exposed test organisms, where higher doses or concentration resulted in an adverse effect.
LOAEL = lowest-observed-adverse-effect-level.
UF = Uncertainty factor, which is a safety factor (100 is mostly used) to account for differences between test animals and human.

As TDIs are regarded as representing a tolerable intake for a lifetime, they are not so precise that they cannot be exceeded for short periods of time. Short-term exposure to levels exceeding the TDI is not a cause for concern, provided the individuals intake averaged over longer periods of time does not appreciably exceeds the level set. The large uncertainty factors generally involved in establishing a TDI serve to provide assurance that exposure exceeding the TDI for short periods is unlikely to have any deleterious effects upon health. However, consideration should be given to any potential acute effects that may occur if the TDI is substantially exceeded for short periods of time.

Source: drinking water – derivation of chemical guideline values (FAO/WHO)

The non-threshold approach applies to chemicals for which any exposure has the potential to cause adverse effects. For these contaminants (e.g. genotoxic carcenogens) an estimation extra lifetime cancer risk can be calculated using a ‘potency’ or ‘slope’ factor. The result can be compared to a level for acceptable cancer risks, internationally varying between about 1 in 10,000 to 1 in 1,000,000. If the calculated risk estimates are less than an acceptable level, it is regarded to be an acceptable situation.

A variety of software models are available to assess risk that contaminated land may pose to Human Health and water resources. The following internationally widely used models are presented and discussed below:

- CLEA
- RBCA
- RISC5
- CSOIL
- MODFLOW
- ConSim
- Remedial Targets Methodology

CLEA

CLEA v1.06 is the most recent release of the Contaminated Land Exposure Assessment (CLEA) Model produced by the Environment Agency. It is fully compliant with the UK technical guidance (SR2-report, Human health toxicological assessment of contaminants in soil, Environment Agency, 2009 and SR3-report, Updated technical background to the CLEA model, Environment Agency, 2009). The model is deterministic.

The CLEA v1.06 model is the software that the Environment Agency has used to derive Soil Guideline Values. It may be used to:

- derive generic assessment criteria (GAC) (basic mode);
- derive site specific assessment criteria (SSAC) (advanced mode) and
- calculate average daily exposure /heath criteria ratios (requires representative media contaminant concentrations).

It offers the following exposure pathways:

- ingestion of soil and soil derived dust
- consumption of homegrown produce (vegetables and fruit)
- consumption of soil attached to homegrown produce (indirect)
- dermal contact with soil and soil derived dust;
- inhalation of soil derived dust (indoors and outdoors) and
- inhalation of soil derived vapours (indoors and outdoors).

The following land-use scenarios, with standard assumptions from SR3 are already present within the model:

- residential with consumption of homegrown produce;
- (Residential without the consumption of homegrown produce);
- allotments and
- commercial.

There is also a series of standard building types and soil types. Users may adapt the land-use scenarios, building types and soil types already present, or may add their own to the database.

The CLEA v1.06 model has a chemical database which contains all the physical-chemical data present with the SR7 report and all the toxicological data within individual published TOX reports (contaminants in soil: updated collation of toxicological data and intake values for humans, Environment Agency) published since 2008. Users may add their own contaminants to the database.

The CLEA v1.06 model does not incorporate sub-surface water pathways. The model output will flag when a saturation limit (either solubility or within the vapour phase) is reached, but does not limit the assessment criteria at the saturation limit. Only on-site users are considered. The CLEA v1.06 model allows a user to incorporate bioaccessibility considerations, but not to include biodegradation. It is possible to incorporate media concentrations, such as those in soil vapour, indoor air or homegrown produce. It cannot model behaviour of free product.

RBCA

The most recent version of the RBCA Toolkit for Chemical Releases produced by GSI Environmental (a US-organization) is v2.6. It has been designed to meet the requirements of the ASTM Standard Guide for Risk-Based Corrective action (E-2081). The model is deterministic and has been designed to:

- calculate baseline risk levels and
- derive “risk based cleanup standards” (assessment criteria).

Theoretically, the model can be used at both Tier 1 (i.e. generic risk assessment) and Tier 2 (detailed quantitative risk assessment) however, because Tier 1 incorporates a range of US assumptions and is not compliant with SR2 or SR3,therefore in the UK users will need to use Tier 2.

The RBCA Toolkit v2.6 incorporates the following pathways:

- groundwater ingestion;
- surface water recreational contact and fish consumption
- incidental ingestion of surface soils;
- dermal absorption of surface soils;
- inhalation of particulates from surface soils;
- inhalation of vapours from surface soils (outdoors and indoors);
- inhalation of vapours from subsurface soil sources (outdoors and indoors) and
- inhalation of vapours from subsurface water sources (outdoors and indoors).

The following standard land-use scenarios, incorporating default ASTM assumption are already present within the model:

- residential and
- commercial.

These can be adapted and, in addition, it is possible to create a user-defined receptor. Both on-site and off-site receptors can be considered. Users can adapt the default buildings and soil parameters.

The chemical database of RBCA Toolkit for Chemical Releases v2.6 is based on the database published by the Texas Commission of Environmental Quality along with Dutch and UK databases. However, the model is able to operate with multiple database files, rather than just by adapting the default database, so that users can select the one they need that complies with technical guidance in the country in which they are operating.

The RBCA Toolkit limits assessment criteria at the saturation limit and indicates where this is the case. The model allows the user to incorporate soil and subsurface water source depletion. It is not readily possible to incorporate concentrations in media other than soil and groundwater. It cannot model behaviour of free product.

RISC 5

RISC5 is the most recently released version of the model which was formerly RISC Workbench, and prior to that BP RISC. The model can be used either deterministically or probabilistically.

It can be used to:

- estimate human health risk from exposure to contaminated media (soil, groundwater, vegetables, sediment) and
- estimate risk-based clean-up levels in various media.

It can be used in a tiered manner, depending on whether default assumptions are altered or not.

It incorporates the following pathways:

- ingestion of soil;
- dermal contact with soil;
- ingestion of subsurface water;
- dermal contact with subsurface water;
- inhalation in the shower;
- inhalation of vapours in outdoor air;
- inhalation of vapour in indoor air;
- inhalation of dusts;
- inhalation of surface water (swimming);
- dermal contact with surface water (swimming);
- dermal contact with sediment;
- ingestion of sediment;
- irrigation pathways (ingestion, inhalation, dermal contact);
- consumption of vegetables grown in contaminated soil and
- ingestion of vegetables irrigated with contaminated groundwater.

There are a number of receptor profiles incorporated, including adult residents and workers and child residents. An additive receptor, which considers a receptor exposed as both a child and an adult is also included. Users can create new receptor profiles.

There are a number of default soil types present within the model and users may both adapt these and create new soil types. Building parameters can be edited. There is a chemical database which users can edit. The default toxicological parameters are USEPA values.

Media concentrations can be entered directly into the model. The model incorporates a number of different models for source depletion, including biodegradation during transport through the unsaturated zone. There are different fate and transport models, depending on whether or not free product is present.

CSOIL

The Dutch CSOIL exposure model for human risk assessment of soil contamination was developed in 1994 and updated in 2000 to determine the Dutch intervention values, to be used for assessment of the need for remediation. CSOIL calculates the risks that humans are exposed to if they come into contact with soil contamination. Humans can be exposed to contaminated soil via different exposure routes (soil, air, water and crops). The soil use, such as a vegetable garden, determines the measure of exposure. Physical-chemical properties of the contaminant in soil air, soil particles and groundwater also have an influence on the exposure. CSOIL 2000 also calculates the maximum concentration of a contaminant in the soil at which it is still safe for humans. This maximum concentration influences the level of the intervention value. In soil contamination the intervention value differentiates between slightly and seriously contaminated soils. The urgency of remediation is therefore determined by the level at which soil contamination exceeds the intervention value. For further information: National Institute of Public Health and the Environment, The Netherlands, RIVM report 711701054/2007

The model incorporates the following pathways:

- direct ingestion of soil and soil derived dust;
- consumption of vegetables that have taken up contamination from soil;
- inhalation of soil vapours outside;
- inhalation of soil vapours inside;
- dermal contact with soil outside;
- dermal contact with soil derived dust inside;
- inhalation of soil-derived dust outside;
- inhalation of soil-derived dust inside;
- inhalation of subsurface water vapours outside and inside;
- ingestion of contaminated groundwater both directly and through permeation of plastic pipes;
- inhalation of vapours during showering;
- dermal contact during showering;

The default land-use scenario is a residential small-holding, but a new land use scenario can be created by altering pathways, receptor and exposure factors. Users can adapt the default soil and building parameters.
The default toxicological database is based on the physical-chemical and toxicological parameters used within CSOIL to derive the Dutch Intervention Values. It is possible to insert measured concentrations for all media. It is not possible to include incorporate degradation rates or bioaccessibility. It can model behaviour of free product.

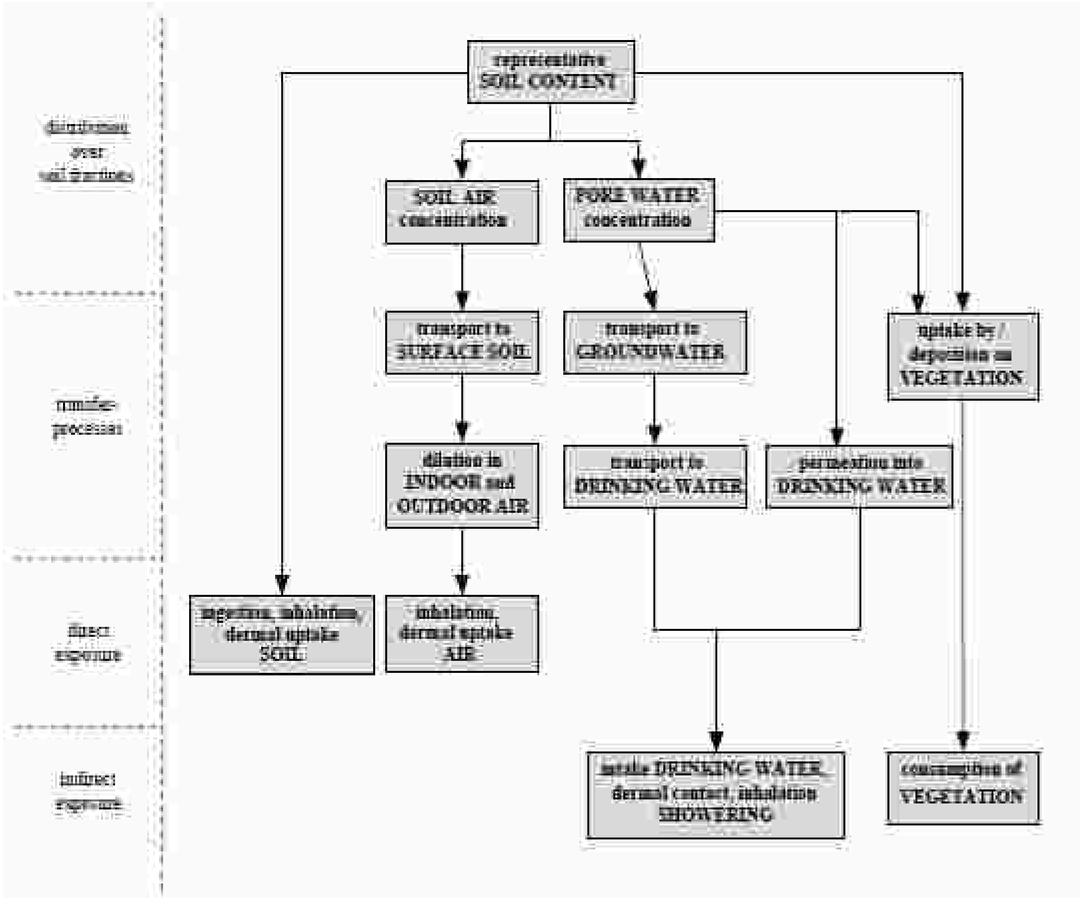


Diagram showing the exposure routes of the model, CSOIL 2000 (RIVM, 2007).

Groundwater and transport models

For the understanding of transport of contaminants in the subsoil, and therefore also of the distribution of a contamination in the soil, groundwater movement and transport of substances can be modelled. The model should be appropriate regarding the required information in the specific situation and the quality of the data of the site. If the soil profile and the spatial variation therein are only partly known, a simple model may provide insight into average linear transport. In case this is not providing sufficient information, more data of the subsoil should be collected before a more complicated modelling can be applied.

Groundwater models describe the groundwater flow and transport processes using mathematical equations based on certain simplifying assumptions. These assumptions typically involve the direction of flow, geometry of the aquifer, the heterogeneity or anisotropy of sediments or bedrock within the aquifer, the contaminant transport mechanisms and chemical reactions. Because of the simplifying assumptions embedded in the mathematical equations and the many uncertainties in the values of data required by the model, a model must be regarded as an approximation and not an exact duplication of field conditions.

Before selecting any of the assessment models or tools, it is vital to have a sound conceptual model of the site. It is also important to have a sound dataset before starting the modelling. It is essential to use the appropriate tool and to interpret the results with a clear understanding of the applicability, accuracy, precision and relevance of its inputs and outputs.

Below three models are illustrated: CONSIM and Remedial Targets Methodology by UK Environment Agency and MODFLOW by USGS.

MODFLOW

MODFLOW is a widely used groundwater flow model for simulating and predicting groundwater conditions and groundwater/surface-water interactions. The most widely used numerical groundwater flow model is MODFLOW which is a three-dimensional model, originally developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988).

Originally developed and released solely as a groundwater-flow simulation code later on many codes were added including for simulation of contaminant transport. The group of MODFLOW-related programs now includes capabilities to simulate coupled groundwater/surface-water systems, solute transport, variable-density flow (including saltwater), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management.

CONSIM

ConSim is a probabilistic model that uses the Monte Carlo simulation technique to select values randomly from each parameter range for use in the calculations. Repeating the calculations many times gives a range of output values, the distribution of which reflects the uncertainty inherent in the input values. This enables you to determine the likelihood of the estimated output values being realised.

CONSIM uses a tiered approach to the assessment of risk to groundwater which predicts contaminant concentrations at several stages along the pathway between the source and the receptor and allows a comparison with appropriate water quality standards. ConSim follows a tiered approach, based on that outlined by the R&D 20 (Environment Agency 1999). The tiers in ConSim are not directly equivalent to those described in R&D 20, and they have therefore been termed 'levels' to avoid confusion. The levels may be summarised as follows:

Level 1. Contaminant Source Assessment.

Level 1 is the simplest stage in a ConSim assessment, which produces contaminant concentrations in porewater within the contaminated soil. The assessment directly incorporates the results of leachate testing, or predicts porewater concentrations based on the results of soil concentration analyses and solid/liquid/gaseous partitioning effects. Level 1 assumes no dilution or attenuation of the contamination and is thus the most conservative of the three assessments.

Level 2. Unsaturated Zone Transport, Aquifer Dilution.

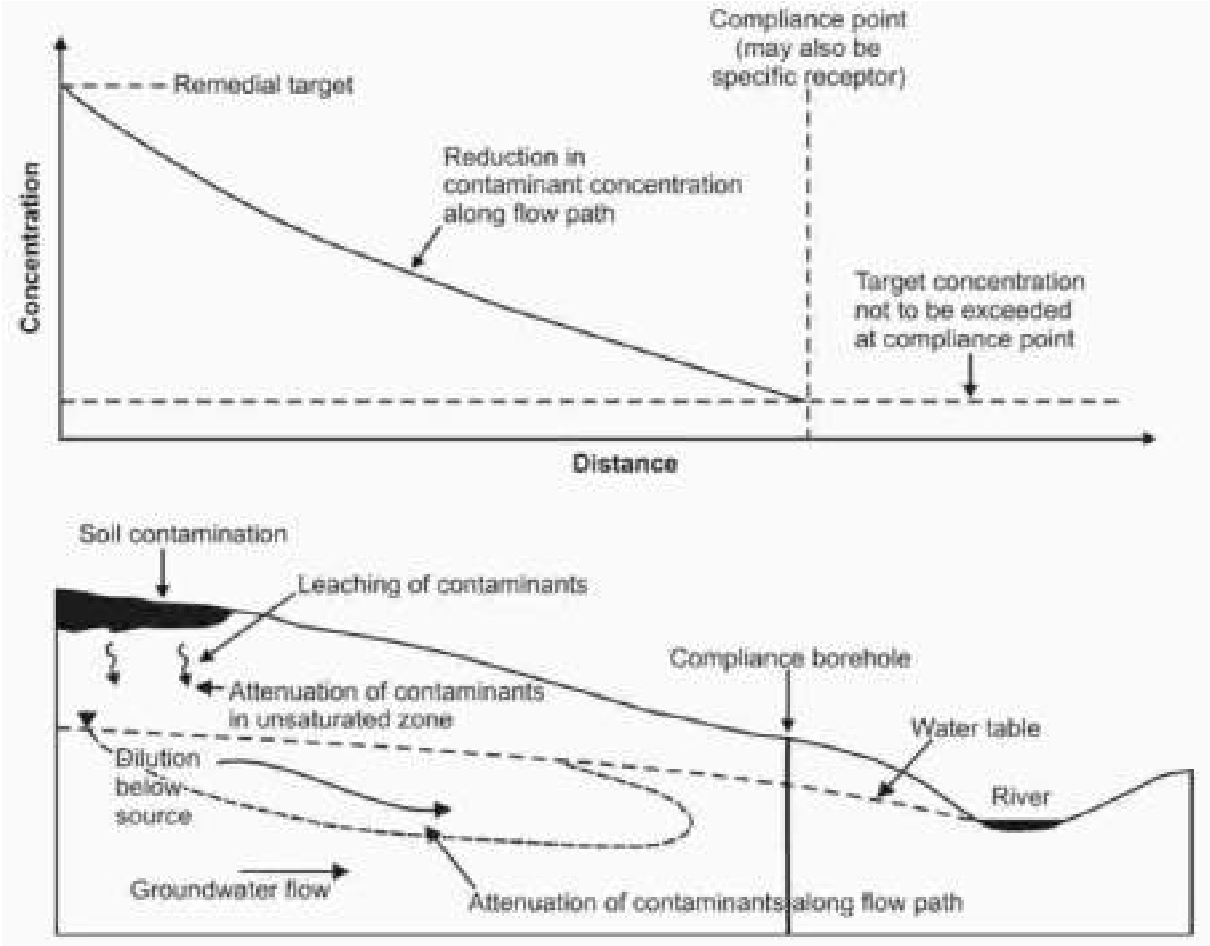
A Level 2 assessment includes a Level 1 assessment, and there are three additional parts; an assessment of the time required for contaminants to migrate from the contaminated soil to the base of every unsaturated pathway, an assessment of the concentration of contaminants at the base of every unsaturated pathway, and a preliminary assessment of the concentration of contaminants at the point of maximum dilution in the aquifer, if sufficient data are available. The effects of biodegradation/decay and retardation can be included if you wish, and both fractured and porous unsaturated zones may be considered. A Level 2 analysis can be completed with a soakaway to allow intense recharge to be simulated. As Level 2 allows for the effects of retardation, degradation and dilution, the results are less conservative than those which are generated by a Level 1 assessment.

Level 3. Saturated Zone Transport.
A Level 3 assessment includes Level 1 and 2 plus an assessment of the time for contaminants to reach a receptor at some distance from the site and the concentrations of contaminants to be expected. You can include the attenuating effects of biodegradation/decay, retardation and dispersion.
At each stage, the calculated contaminant concentrations may be compared with selected water quality standards to indicate the magnitude of the risk posed to groundwater.

Level 3a
The Level 3a module allows the user to omit the unsaturated zone and directly input groundwater concentrations. This option can be used to simulate the movement of contaminants that have passed through the soil zone (e.g. an underground storage tank beneath the water table, or where the soil source has been removed). Level 3a is equivalent to a Tier 3 groundwater analysis in R&D Publication 20 (Environment Agency, 1999).

Level 4
ConSim performs the necessary calculations using Laplace transforms to solve the groundwater flow and contaminant transport equations. The fourth tier described by The Environment Agency (1999) comprises detailed numerical groundwater flow and contaminant transport modelling. This type of calculation is outside the intended application of ConSim, but it may be necessary to carry out further, more detailed, modelling if the hydrogeological regime is complex, or if the sensitivity of the receptor warrants additional expenditure.

Remedial Targets Methodology
The Environment Agency Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination guidance document and accompanying spreadsheet allow the derivation of remedial target concentrations for contaminants in soils and groundwater. These target concentrations should not be exceeded at compliance points which have to be determined along the contaminant pathway (refer to below picture which illustrates the compliance point relationship with Remedial Targets Methodology (source: Groundwater protection, Principles and Practice, UK-Environment Agency, 2013).



The methodology was developed to derive site-specific remedial objective for contaminated soils and/or groundwater and to protect the aquatic environment. It is based on a phased approach to risk assessment and management as set out in UK government guidance. The approach is underpinned by progressive data collection and analysis, structured decision making and cost benefit assessment.

The methodology applies to soils and groundwater that is already contaminated, where the original surface source of the contamination has ceased and consists of up to four assessment levels which progressively follow the pathway from the contaminant source through to the receptor. A remedial target is derived at each level, but this likely to be less stringent at the next level as additional processes such dilution attenuation are taken into account.

At level one the assessor considers the initial conceptual site model and evidence of pollutant linkages. The assessor then evaluates whether contaminant concentrations in pore water in contaminant soil are sufficient to impact the receptor but ignores dilution, dispersion, and attenuation along the pathway.

At level two the assessor considers the possible effect of attenuation processes in the soil and unsaturated zone, and predicts the effects of dilution by groundwater flow beneath the site.

At level three, the assessor considers the effects of attenuation between the site and a downgradient receptor and can include such processes as:

- dilution;
- dispersion;
- retardation;
- degradation by biotic of abiotic processes and
- other attenuation processes.

Finally, at level four, the assessor can consider whether it is appropriate to take account of dilution in the receiving watercourse or abstraction.

4 More information

More detailed information on risk assessment methodologies is available via specialized websites of governmental organizations and research institutes:

- http://www.neeri.res.in/
  National Environmental Engineering Research Institute (NEERI), Nagpur

- http://www.nih.ernet.in/
  National Institue of Hydrology, Roorkee
  Providing for learning package for hydrology:
  http://www.nih.ernet.in/rbis/learning.htm#Groundwater

- http://ngri.org.in/
  National Geophysical Research Institute (NGRI), Hyderabad

- Concepts and Modeling of Groundwater System, C.P. Kumar, S. Singh, National Institute of Hydrology, in International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 2, February 2015

- https://www.gov.uk/government/collections/land-contamination-technical-guidance
  Link to information and examples UK

- http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2014/ec/En163-1-16-eng.pdf
  link to Technical Assistance Bulletin nr 16 on Risk Assessment-Exposure Model, Toxicity analysis and Evaluation, Canada

- http://esrd.alberta.ca/lands-forests/land-industrial/inspections-and-compliance/alberta-soil-and-groundwater-remediation-guidelines.aspx
  Alberta Environment and Parks government, links to Tier 1 and Tier 2 Soil and Groundwater Remediation Guidelines.

- http://www.epa.gov/risk_assessment/guidance.htm
  link to information and examples of US-EPA risk assessment

- http://www.epa.gov/land-research/models-tools-and-databases-land-and-waste-management-research
  link to information and examples of US-EPA Models, Tools, and Databases for Land and Waste Management Research

- http://water.usgs.gov/software/lists/groundwater/#var-saturated
  link to information and examples of USGS Water Resources Groundwater Software such as MODFLOW

- https://clu-in.org/docs/embed.cfm?link=%2Fpublications%2Fdb%2Fdb%5Fsearch%2Ecgi%3Ftitle%3D1%26cat1%3D1%26submit%5Fsearch%3D1
  website of the US-EPA Contaminated Site Clean-Up Information, section characterization and monitoring

- http://www.unido.org/what-we-do/environment/implementation-of-multilateral-environmental-agreements/o591190100/e-learning/unido-contaminated-site-investigation-and-management-toolkit.html
  link to toolkit UNIDO

  PERSISTENT ORGANIC POLLUTANTS: CONTAMINATED SITE INVESTIGATION AND MANAGEMENT TOOLKIT, UNIDO
  A contaminated site investigation and management toolkit for Persistent Organic Pollutants has been developed by UNIDO. Module 3 of this Toolkit report provides guidelines for assessing the human health risks. It outlines how to conduct a generic Tier 1 approach, in which the information collected during the site investigation is used to compare contaminant concentrations against the recommended values for soil and groundwater.
  Tier 1 is a set of generic guidelines that provide simple tabular values that were developed based on conservative scientific assumptions about soil and groundwater characteristics. Two of the three risk assessment components, receptors and pathways, are already built into a Tier 1 assessment; therefore only the contaminants need to be considered.

  This module also presents the basis steps of a Site-specific Risk Assessment, identifying a site's contaminants, exposure pathways and receptors. This can be used as the basis for developing a risk management process in situations when complete remediation is not a viable option for a contaminated site.

Volume III

5.4-i Overview remediation techniques and menu of options

Volume III-5.4-i
Overview remediation techniques and menu of options

1 Introduction

This information is most relevant for Task 5.4, Development of remediation options. This sections presents information and tools applicable when performing site remediation investigation. First the driving principles of remediation techniques are presented (section 2). Then an overview is presented of available remediation techniques and their applicability (section 3). Section 4 provides information on remediation techniques and for each technique descriptions, specific characteristics and SWOT[1]-analysis is provided. Finally section 5 provides a menu of prioritized remediation options for all types of contaminated sites.

2 Remediation techniques – driving principles

There are five major driving principles behind remediation techniques:

- Extraction: removal of the unaltered contaminant from the ground/sediment or groundwater in which it is located (for treatment elsewhere);
- Transformation: the destruction or alteration of the contaminant into a less or non-harmful product;
- Immobilization: stopping of the migration of the contaminant in its pathway;
- Containment: capturing the contaminant within non penetrable physical boundaries;
- Temporary safety measures: shielding the receptor itself from contact with the contaminant.

Table III-5.4.1 presents these five driving principles, together with some examples of their incorporation into remediation techniques and approaches.

[1] Strengths, Weaknesses, Opportunities & Threats

Table III-5.4.1 Driving principles of remediation techniques and examples

Principles	Localisation	Type	Examples of techniques
Extraction	On site Soil treatment off-site	Physical	Excavation SVE – Soil vapor extraction SVE – Soil vapor extraction MPE – Multi phase extraction
	On site Soil treatment on-site	Physical / Biological / Chemical	Biological treatment / Biopiles On site soil processing with mobile soil washer plant and reuse of treated soil
Transformation	In-situ	Chemical	In-situ chemical oxidation (ISCO) Air-sparging
	In-situ	Biological	In-situ bioremediation, natural attenuation
Immobilization	In situ	Physical	Chemical immobilisation Vitrification
Containment	In-situ	Physical	Vertical wall Capping layer Geohydrological control
Temporary safety measures	On-site	Physical Social Legal	Alternative water supply, treatment of pumped groundwater Fencing/signage Land access restrictions Notification and administrative obligations

3 Available remediation techniques and their applicability

This information is most relevant for Task 5.4 Development of remediation options. This Section presents, in table III-5.4.2 below, a brief overview of available remediation techniques and their applicability towards source/pathway/receptor and types of contaminating substances. In certain cases a combination of techniques has to be applied to reach the intended remediation objective.

Table III-5.4.2 Overview of remediation techniques and their applicability

✓ Remediation option is potentially applicable to a specific media-contaminant combination
X Remediation option is not applicable to a specific media-contaminant combination
? A pre-treatment step or pilot may be necessary prior to the method being suitable or case study information is inconclusive regarding applicability
S Soils, made ground en sediments
W Groundwater and surface water

Principle	Technique	Section	Point of entry (SPR)			Applicable media	Applicability substances									
			Source	Pathway	Receptor		VOC's (volatile organic components)	Halogenated Hydrocarbons	Non-halogenated Hydrocarbons	PAHs (polycyclic aromatic hydrocarbons)	PCBs (polychlorinated biphenyls)	Dioxins and furans	Pesticides and herbicides	Heavy metals	Asbestos	Cyanides
Extraction	*Excavation, followed by:*	*4.1*	*X*	*X*	*X*	*S*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	- Biological treatment / biopile	*4.1.1*	*X*	*X*	*X*	*S*	✓	X	✓	✓	X	X	✓	X	X	X
	- Soil washing	*4.1.2*	*X*	*X*	*X*	*S*	X	✓	✓	✓	✓	X	✓	✓	X	✓
	- Thermal treatment	*4.1.3*	*X*	*X*	*X*	*S*	✓	✓	✓	✓	✓	✓	✓	X	X	✓
	- Physical separation	*4.1.4*	*X*	*X*	*X*	*S*	X	X	X	X	X	X	X	X	✓	X
	- Disposal in landfill	*4.1.5*	*X*	*X*	*X*	*S*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Groundwater abstraction (pump & treat)	*4.2*	*X*	*X*		*W*	✓	✓	✓	✓	✓	✓	✓	✓	X	X
	SVE – Soil vapor extraction	*4.3*	*X*	*X*	*X*	*S*	✓	✓	✓	X	X	X	X	X	X	X
	MPE – Multi phase extraction	*4.4*	*X*	*(X)*	*X*	*S,W*	✓	✓	✓	?	X	X	X	X	X	X
Transformation	*Air-sparging*	*4.5*	*X*	*X*		*W*	✓	✓	✓	?	X	X	X	X	X	X
	Soil Heating	*4.6*	*X*			*W*	✓	✓	✓	✓	?	X	X	X	X	?
	Elektrokinetics	*4.7*	*X*	*(X)*		*S, W*	✓	✓	✓	✓	?	?	?	✓	X	✓
	In-situ chemical oxidation (ISCO)	*4.8*	*X*	*(X)*		*S, W*	✓	✓	✓	✓	X	X	✓	X	X	?
	Permeable reactive barriers (PRB)	*4.9*		*X*		*W*	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
	In-situ bioremediation	*4.10*	*X*	*X*		*S, W*	✓	✓	✓	✓	X	X	✓	X	X	X
	Phyto remediation	*4.11*	*X*	*X*		*S, W*	✓	✓	✓	✓	X	X	✓	✓	X	?
	Natural attenuation	*4.12*	*X*	*X*		*W*	✓	✓	✓	✓	X	X	✓	X	X	X
Immobilization	*Vitrification*	*4.13*	*X*			*S*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	In-situ grouting	*4.14*	*X*	*X*		*S*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Containment	*Vertical wall*	*4.15*		*X*		*S, W*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Capping layer	*4.16*		*X*		*S, W*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Geohydrological control	*4.17*		*X*		*W*	✓	✓	✓	✓	✓	✓	?	✓	✓	?
Temporary safety measures	*Land use restrictions*	*4.18*			*X*	*S, W*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Relocation and safety measures	*4.19*			*X*	*S, W*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Drinking water treatment	*4.20*			*X*	*W*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Additional sections are added for:

- *Water treatment technologies (section 4.21)*
- *Off gas air treatment technologies (section 4.22)*
- *Recovery of material from remediation activities (section 4.23)*
- *Remediation of sediments (section 4.24)*

4 Remediation techniques – Descriptions, specific characteristics and SWOT[2]-analysis

This information is most relevant for Tasks 5.4 Development of remediation options and 5.5 Selection remediation option.

This Section presents descriptions of the available remediation techniques mentioned in 4.2 and offers their specific characteristics and a SWOT-analysis. These remediation techniques have provided good results internationally and are likely to be applicable in India as well.

Were relevant, *more information* internet links have been created. The purpose of the internet links is to provide more information on the basics of a technology. Application of a technology must always be a site specific consideration.

Following internet sources provide generic information about remediation techniques and examples of cases where techniques have been applied:

- CLU-IN website of US-Environmental Protection Agency providing information about innovative treatment and site characterization technologies: http://www.clu-in.org/
- Federal Remediation Technologies Roundtable website providing information about technologies for assessment and remediation of contaminated sites: http://www.frtr.gov/
- A good overview on standings for in-situ treatments is provided in: http://www.frtr.gov/pdf/meetings/jun08/madalinski_presentation.pdf
- Soilection website providing information and case descriptions of practical in-situ remediation experiences in The Netherlands and Belgium: http://www.soilection.eu
- Dutch directive on restoration and management of soil, groundwater and sediment, provides information on remediation techniques: http://www.bodemrichtlijn.nl/Bibliotheek/bodemsaneringstechnieken (English translation is provided on this internet page)

4.1 Excavation

Excavation is based on the driving remediation principle of extraction. The contaminated soil is extracted by means of excavation. This is an ex-situ technique by localisation. The physically extracted soil has to be treated further to further reduce the risk related to the contaminant. Various techniques for soil treatment exist and some of them can be implemented both on-site and off-site.

Remediation level

In general excavation enables a high degree of contaminant removal paired with a high degree of control and accuracy. In particular for shallow contamination, removal of all contaminant is technically feasible.

[2] Strengths, Weaknesses, Opportunities & Threats

Technical risks
Soil excavation can be a very robust technique. The technical risks of soil excavation are related to the presence of buildings, foundations or other objects above or below ground. A good insight in the presence of all these objects before start of the excavation can significantly reduce the technical risks. The risks increase with increasing depth of excavation and excavation below the natural groundwater level.
Many remediation projects where excavation is applied exceed financial budgets. This is related to the excavation of larger volumes of contaminated soil than estimated. To control this risk, excavation requires a well defined CSM[3] and proper delineation of the contamination.

Costs
The costs of an excavation are directly linked to the volume of soil to be excavated and treated. In particular the treatment of the excavated soil and the transport of the excavated soil to a treatment facility are determinant for the costs of this technique. Refilling of the excavation pit with suitable quality soil can also be a major factor in costs.

Sustainability
Excavation equipment and trucks for transportation of the excavated soil are energy consuming and produce significant amounts of CO_2. Sustainability is also influenced by the treatment for the excavated soil.

Time
Excavation by itself is a relatively fast technique, delivering tangible results with each bucket of contaminated soil that is excavated.

Post remedial use
Given total removal of the contamination and backfilling with suitable quality soil, a site can be restored to full multifunctional use.
The post remedial use of a site that has been remediated by excavation can be limited when contamination has been left behind in soil and/or groundwater and on the quality of the soil applied for filling the excavation.

Social criteria
During a remediation by excavation the site is generally off bounds to other uses. The function of the site is temporarily lost.

Excavation equipment and trucks may cause local nuisance (noise, dust, smell, traffic, vibrations).

Lowering the groundwater table during excavation may cause consolidation of soil and lead to damage to neighbouring buildings.

The application of vertical walls (sheet piling) to enable excavation may cause vibrations (nuisance and/or damage to neighbouring buildings).

[3] Conceptual Site Model

SWOT: Strengths
Remediation by excavation can deliver robust results and can be completed in a short time. Remediation up to full multifunctional restoration can be possible.

SWOT: Weaknesses
During excavation the site is unavailable for other uses. Soil logistics (excavation, transportation) have significant energy consumption. Costs are strongly related to the volume of soil to be excavated, transported and treated.

SWOT: Opportunities
Excavation can offer a fast and final solution for relatively small and shallow contaminations.
Excavation is a prime candidate as remediation technique for dynamic sites in an urban setting which require fast results.
Remediation by excavation can be combined with other civil works, if the remediation dig has been considered in the civil design (example: the space created by the excavation becomes part of the underground parking space/tunnel).

SWOT: Threats
In populated areas nuisance issues and risk for neighbouring buildings and objects are to be carefully taken into account.
Lack of working space can seriously hinder the logistics of excavation, increasing the costs and the risk of longer remediation duration. Lack of working space is typical of excavating in urban areas, where time is also of the essence.

More information
http://www.frtr.gov/matrix2/section4/4-29.html

http://www.egr.msu.edu/tosc/dutchboy/factsheets/what%20is%20excavation.pdf

http://www.abdk.nl/html/media/documenten/CO%20Folder%20Corporate%20Engels%202008.pdf

4.1.1 Excavation: soil treatment by biological treatment / biopiles

Biological treatment and biopiles are both based on the driving remediation principle of transformation. On-site biological treatment is generally indicated with the term landfarming. It should be emphasized that landfarming as remediation technique is not allowed in India due to agricultural policy. However we will use this term in the text below because of the generic use of this technique internationally. In both techniques, the contaminants in the soil are biologically transformed into less or non-harmful products. Biopiles are basically a more engineered form of landfarming. Both techniques share many characteristics.

Landfarming consists of cultivating the contaminated soil in lined bed in layers of 0.5 up to 1 meter thick. The beds are periodically turned over to improve the oxygen supply and the structure of the soil.

Biopiles are a more engineered version of landfarming in which the contaminated soil is places in mounds between 0.5 and 3 m in heights. Oxygen can be actively supplied by air injection or extraction. Generally the soil in a biopile is also supplied with nutrients and moisture. If needed, soil structure can be improved (for example with fine gravel), pH can be buffered (for example with lime) and temperature within the biopile can be regulated.

Remediation level
Landfarming/biopiles are applicable to biodegradable organic contaminants. Total removal of the biologically available fraction of the contamination is the expected result. For volatile, mobile compounds this generally implies near total removal. For heavier organic contaminants a certain amount of biologically unavailable residual contamination has to be taken into consideration.

Technical risks
Heavier organic compounds are more difficult to degrade. This can result in a longer remediation time and higher remediation level. Contamination levels that exceed microbial growth inhibition levels will severely hamper degradation.

Conditions within the bed/pile must be maintained favourably towards aerobic degradation by micro organisms. In particular temperature, oxygen, moisture, nutrients, soil structure, temperature and pH are of importance.

Care has to be taken to prevent unwanted cross contamination of the underlying soil, this includes mixing as well as (rain-) water seepage.

Costs
The costs of landfarming/biopiles consist of two elements:
- installation costs (lining, aeration equipment, space);
- operational costs (piling, periodic turning over of beds, aeration, monitoring, nutrients).

The installation costs are linked to the volume of soil to be treated and the degree of engineering of the system. The operational costs are determined by the amount of handling and the volume of the soil. The amount of handling is linked to the biodegradability of the contamination.

Sustainability
Landfarming/biopiles are generally considered to be sustainable soil treatment techniques, especially when the treated soil is reused for backfill the site instead of backfilling with pristine soil.

Time
The duration of soil treatment by landfarming/biopiles depends largely on achieving the suitable conditions for degradation. Under optimal conditions, the treatment generally has a duration between 3 to 9 months. In a temperate climate, landfarms and biopiles are generally considered to be inactive during late fall, winter and early spring, causing landfarms/biopiles to have a duration measured in one or two summers rather than in months.

Post remedial use
It is likely that a degree of residual contamination has to be taken into consideration after using landfarming/biopiles.
Soil treated by landfarming/biopiles retains its biological functions. Any biological functions this soil had before treatment will be preserved.

Social criteria
The site of the landfarming/biopiles is generally off bounds to other uses. The function of the site is temporarily lost.

Excavation equipment and trucks for transportation may cause local nuisance (noise, dust, smell, traffic, vibrations).

SWOT: Strengths
Given the right climatic circumstances and soil composition, landfarming/biopiles are very efficient at treating organic pollutants, while requiring relatively little effort.

SWOT: Weaknesses
Landfarm/biopiles take time and use space. The optimum result (backfilling with the treated soil) implies delayed backfilling. Planning ahead is vital.

SWOT: Opportunities
Having the landfarm/biopile on site, and using the treated soil to backfill the excavations, removes the need to obtain suitably reusable soil from other parties and eliminates much of the cross media effects caused otherwise by transportation and treatment in specialized installations elsewhere.

SWOT: Threats
A landfarm/biopile will emit a part of the volatile fraction of its contaminants to the outside air. These volatile organics can be potentially harmful, but more often they are also odorous. It is recommended to operate a landfarm/biopile on a suitable distance from populated areas.

More information
http://www.epa.gov/oust/cat/biopiles.htm

http://www.frtr.gov/matrix2/section4/4_11.html

4.1.2 Excavation: soil treatment by soil washing

Soil washing is based on the driving remediation principle of extraction. In soil washing, the majority of the contamination is separated from the bulk soil by consecutive separation steps, using separation on size, washing with water, optionally washing with water enhanced with acids/alkalis/complexants and/or surfactants and gravitational separation. The process employs standard mineral processing equipment like screens, scrubbers, hydrocyclones, flotation cells and/or dewatering filters.

The fraction of fine silt and clay particles that contains most of the residual contamination has to be disposed at a hazardous waste landfill or be treated further by chemical, thermal or biological processes.

Remediation level
The clean sandy fraction is typically of suitable quality to be reused on site or be reused elsewhere for less sensitive uses like infrastructural works.

Technical risks
The fine content (silt and clay, typically specified as particles smaller than 63 µm) retaining the contamination has to be exposed of by expensive means, so it is vital to keep this content as low as possible without cross contaminating the treated sand fraction.

Clay, silt and peat will generally result in more fine content than treated sand fraction and are therefore unsuitable soil compositions for soil washing.

Costs
The fine content determines much of the total costs of treatment by soil washing Depending on local economics, anywhere from above 20% to 40% by weight of particles smaller than 63 µm is considered not to be economically treated by soil washing.

Soil washing water will likely have to be processed before it can be reused or discharged. This represents additional costs.

Sustainability
Soil washing is not a typically sustainable soil treatment technique. The main reason being soil washing does not actually remove contamination; rather it concentrates and transfers it into a lesser fraction of the original soil. Another factor can be transportation, if the soil washing installation is not available on-site.

Time
Soil washing is a relatively fast treatment process.

Post remedial use
Soil treated by soil washing has lost much if not all of its fine content. It will have lost most of its contaminants but often some residual contamination remains. The treated sand fraction typically is reusable in less sensitive uses like infrastructural works and land levelling for non-residential and non-agricultural uses.

Social criteria
Excavation equipment, trucks for transportation and mineral processing equipment for soil washing may cause local nuisance (noise, dust, smell, traffic, vibrations).

SWOT: Strengths
The strength of soil washing is its ability to treat most organic compound as well as heavy metals and cyanides in sandy soils.

SWOT: Weaknesses
Soil washing is not suitable for soils with a fine content of more than 20 to 40 % by weight.

SWOT: Opportunities
Soil washing installations are typically relatively small in size, enabling mobile versions of the installation. Given a large enough volume of soil to be treated, a mobile soil washer can considerably cut costs, especially if the treated sand fraction is reused for backfilling the excavation.

SWOT: Threats
Permanent soil washing installations may not be available or may be at considerable distance from the remediation site.

More information
http://www.frtr.gov/matrix2/section4/4-19.html

http://chemeng.queensu.ca/courses/CHEE484/documents/FortuneMelanie_SoilWashing.pdf

4.1.3 Excavation: soil treatment by thermal treatment

Thermal treatment is based on the driving remediation principle of transformation. Typically thermal treatment is employed in a rotary kiln and operated at high temperatures of anywhere between 90 to 600 °C (mostly thermal desorption/evaporation) to as high as 1.300 °C (mostly thermal destruction). The process results in thermal desorption and/or thermal destruction of the contamination, depending on the temperature of operation. Using thermal treatment most organic contaminants can be removed from a wide range of soil compositions including silt, clay and mineral-rich peat. Also a degree of removal of volatile metals can be achieved, depending on temperature of operation.

Remediation level
Using thermal treatment, high and reliable levels of removal up to total removal of contaminants, can be achieved.

Technical risks
The contaminated soil may need pre-treatment to remove clumps and oversize material.

Thermal treatment of mineral-poor peat can lead to uncontrollable thermal processes and is not recommended.

In particular by thermal desorption processes incomplete combustion products can be formed, such as dioxins/furans. The possible emission of these compounds as well as dust and particulates requires careful air emission control and proper off gas treatment.

Costs
Costs for thermal treatment are typically high, as the process requires large amounts of fossil fuel for heating the kiln. Also the costs are determined by transportation, pre-treatment and off-gas treatment.

Sustainability
Thermal treatment is not a typically sustainable soil treatment technique. The main reasons being the energy consumption and the loss of most of the biological function of soil treated at the higher temperature ranges (above 300 °C). It can however be the only alternative to disposal at a hazardous waste landfill and therefore still be the preferred method.

Time
Thermal treatment is a relatively fast treatment process in itself. The throughput of a thermal treatment plant depends mostly on equipment capacity and soil moisture content. Typically thermal soil treatment plants will bulk up such amounts of treatable soil as to keep their process running continuously over longer times, and prevent relatively costly start-ups and shut-downs as much as possible.

Post remedial use
Thermally treated soil typically is reusable in less sensitive uses like infrastructural works and land levelling for non-residential and non-agricultural uses.

Thermally treated soil at temperatures above 300 °C will have lost most of its biological function due to loss of structure and (partly or totally) organic matter. Such treated soil is a distinctively dark grey to black coloured, ashy granular substance. This limits reuse to uses that do not require any biological function of the soil nor have high soil structure demands.

Social criteria
Excavation equipment, trucks for transportation and thermal treatment equipment for soil washing may cause local nuisance (noise, dust, smell, traffic, vibrations).

Possible emissions of incomplete combustion products as dioxins and furans may cause local concerns over air quality.

SWOT: Strengths
The strength of thermal treatment is its ability to treat most organic compound as well as some heavy metals to some extent in silt and clay and mineral-rich peat containing soils.

SWOT: Weaknesses
Thermal treatment is expensive with high energy costs. Reuse of the treated soil may be limited because of loss of structure and (part of) organic matter, depending on temperature of operation.

SWOT: Opportunities
Soil thermal treatment installations are also available in mobile versions. Given a large enough volume of soil to be treated, a mobile soil treatment plant can considerably cut costs, especially if the treated soil can be reused for backfilling the excavation.

SWOT: Threats
Permanent soil thermal treatment installations may not be available or may be at considerable distance from the remediation site, depending on the economic circumstances.

Mobile soil thermal treatment installations may cause local concerns over emission of incomplete combustion products such as dioxins/furans.

More information
http://www.clu-in.org/download/Citizens/a_citizens_guide_to_thermal_desorption.pdf

http://www.epa.vic.gov.au/~/media/publications/1402.pdf

4.1.4 Excavation: soil treatment by physical separation

Physical separation is based on the driving remediation principle of separation. The particulate matter containing the contamination is, after excavation removed from the bulk soil by physical separation or size and handpicking. The process employs standard mineral processing equipment like screens and conveyor belts, water spraying units, and specialized equipment like (contained) asbestos picking stations and asbestos scrubbers.

This technique is most often used for the removal of asbestos containing materials from the soil. After removal from the soil, the asbestos and asbestos containing fine fractions have to be properly sealed before transport and subsequently disposed at a hazardous waste landfill.

The technique of physical separation is also widely used to separate rubble from soil or to prepare selected soil particle sizes. If contamination is related to rubble or a specific particle size, the technique can be used to remove contaminations from the excavated soil.

Remediation level
Asbestos can be near-totally removed from soil, provided the soil is suitably for screening. Remediation levels for other substances are very much dependent on the specifics of the materials to be processed.

Technical risks
Fine content (silt and clay, typically specified as particles smaller than 63 µm) containing soil is unsuitable for asbestos removal by screening.

Emissions to air of asbestos fibres during storage and transport have to be taken into consideration and may require soil moisture content control and/or sealing.

Emissions to air of asbestos fibres and particulates during treatment have to be taken into consideration and may require contained treatment units with air filtration equipment.

Costs
The operational costs of the equipment and the disposal costs of the asbestos determine much of the total costs of asbestos treatment by physical separation. Additional costs can be caused by asbestos exposure control, in particular when treating non matrix-bound asbestos containing materials which have a higher potential of fibre release.

Sustainability
Physical separation of asbestos is not a typically sustainable soil treatment technique. The main reason being the asbestos is not actually removed; rather transferred to a hazardous waste disposal.

Time
Physical separation of asbestos from soil is a relatively fast treatment process.

Post remedial use
Soil treated by physical separation is typically reusable in less sensitive uses like infrastructural works and land levelling for non-residential and non-agricultural uses.

Social criteria
Excavation equipment, trucks for transportation and mineral processing equipment for soil washing may cause local nuisance (noise, dust, smell, traffic, vibrations).

Possible emissions of asbestos fibres may cause local concerns over exposure to airborne asbestos.

SWOT: Strengths
The strength of physical separation is its ability to remove asbestos from sandy soils using a standard technology.

SWOT: Weaknesses
Physical separation by screens is not applicable to silt/clay containing soils. Technologies to remove asbestos from these types of soil are becoming available.

SWOT: Opportunities
Mechanical soil screens are particularly mobile and start to be effective already at relatively small volumes of soil to be treated.

SWOT: Threats
Having to operate in containment, due to nearby sensitive uses or the potential to emit fibres from the asbestos (e.g. asbestos pulp), will increase costs.

Treated soil that still contains the slightest bit of asbestos can remain controversial for reuse, despite reaching sufficient removal of asbestos.

More information
http://www.frtr.gov/matrix2/section4/4-18.html

4.1.5 Excavation: soil treatment by disposal in landfill

Disposal of contaminated soil is based on the driving remediation principle of containment. The contaminated soil is permanently contained in a controlled landfill.

Remediation level
The remediation level for a subject site is complete. However, no remediation levels are achieved for the soil in the landfill.

Technical risks
A controlled landfill should be well designed so that all risks for the environment are controlled. This implies a proper bottom liner, control of infiltration of rainwater into the landfill material, treatment of landfill gas, and capping of the landfill after closure.

Emissions to air of contaminated dust and volatile components have to be taken into consideration during land filling and may require soil moisture content control and/or sealing.

Costs
The operational costs of the landfill, transportation to the landfill and taxes determine much of the total costs of disposal to a landfill.

Sustainability
Disposal to a landfill is not considered to be a sustainable remediation technique. Landfills use up land, make the land unsuitable for any other uses.

Time
Disposal of contaminated soil in a landfill is a fast treatment process.

Post remedial use
Soil disposed in a landfill is not reusable. Within the landfill the soil can be used to improve the property of the landfill body.

Social criteria
A landfill can result in many nuisances for its surroundings. Excavation equipment, trucks for transportation and compactors for land filling may cause local nuisance (noise, dust, smell, traffic, vibrations).

SWOT: Strengths
The strength of disposal to a landfill is the ability of the landfill to store all types of contaminated soil directly.

SWOT: Weaknesses
Disposal to a landfill is not a definitive solution. A landfill consumes valuable land.

SWOT: Opportunities
Landfills can be relative simple operations that can store wide varieties of waste including contaminated soil.

SWOT: Threats
The use of landfill in general does not encourage recycling and final solutions for contaminated soil.

4.2 Groundwater abstraction

Groundwater abstraction (*pump & treat*) is based on the driving remediation principle of extraction. The contaminated groundwater is extracted acted by means of abstraction. This is an in-situ technique by localisation. The extracted groundwater has to be treated further depending on the levels of contamination and the risk related to the contaminant. Various techniques for water treatment exist and most of them can be implemented on-site.

Remediation level
The remediation level is very much depended on local conditions and contaminations. Under optimal circumstances, groundwater abstraction can accomplish complete removal of contaminations. In most cases groundwater abstraction can stop the spreading of contamination.

Technical risks
Groundwater abstraction is a proven technology. The permeability of the water bearing layer is critical for the success of groundwater abstraction. The well design for the groundwater abstraction should be based on the permeability, soil conditions and contaminant behaviour

During operation of the abstraction, the effects of well clogging (mechanical and biological) should be monitored.

Costs
The operational costs of groundwater abstraction are determined by the need for additional groundwater treatment.

Sustainability
Groundwater abstraction can be a sustainable technique if the extracted water is after treatment reintroduced in the water bearing layer.

Time
The time involved for groundwater abstraction is fully dependent on the contamination type and related retardation factor of the contamination.

Post remedial use
If properly remediated and treated, both the water in the water bearing layer and the treated water can be reused.

Social criteria
Groundwater abstraction can result in nuisances for its surroundings due to lowering of the groundwater table and related geotechnical consequences (soil settling).

SWOT: Strengths
The strength of groundwater abstraction is the ability to stop spreading of multiple contaminations in water bearing layers directly.

SWOT: Weaknesses
In most situations groundwater abstraction has to be combined with extensive and expensive water treatment installations.

SWOT: Opportunities
The abstracted and treated groundwater can be used locally for various purposes.

SWOT: Threats
The use of groundwater abstraction can result in the loss of valuable water and depletion of water bearing layers.

More information
http://www.clu-in.org/download/citizens/a_citizens_guide_to_pump_and_treat.pdf

http://www.frtr.gov/matrix2/section4/4-48.html

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.3 Soil vapor extraction (SVE)

Soil vapor extraction is based on the driving remediation principle of extraction. SVE creates an under pressure in unsaturated zone of the soil creating a flow of soil air to extraction wells. In this process the volatile contaminations in the unsaturated zone are transported aboveground. The extracted air has to be treated further depending on the levels of contamination and the risk related to the contaminant. Various techniques for air treatment exist and most of them can be implemented on-site.

Remediation level
The remediation level is very much depended on local conditions and contaminations. Under optimal circumstances, SVE can accomplish complete removal of contaminations. In most cases SVE can stop spreading of contamination to the underlying groundwater.

Technical risks
The permeability of unsaturated soil and the volatility of the contaminants are critical for the success of SVE. The risks can be very easy be controlled by implementing a pilot before deciding on the full scale application of SVE.

Costs
Operational costs of SVE are relatively low. Significant additional costs can be endured by the need for off gas treatment.

Sustainability
SVE is not a typically sustainable soil treatment technique. The main reason is the energy consumption of the technique.

Time
The time involved for SVE will always be in the range of months - year.

Post remedial use
Soil treated by SVE is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
A SVE system results in little nuisances for its surroundings due to compact nature of the equipment. To minimize nuisance and odour issues, off gas treatment has to be applied if levels require so.

SWOT: Strengths
The strength of SVE is the ability to stop spreading of contamination to the underlying groundwater. SVE also stimulates the aerobic degradation in the unsaturated zone. and allows for additional techniques such as air-sparging, to be applied with little extra costs.

SWOT: Weaknesses
The application of SVE is limited to a very specific, limited range of contaminants. In most situations SVE has to be combined with extensive and expensive air treatment installations.

SWOT: Opportunities
The implementation of SVE allows for additional techniques such as air-sparging, to be applied with little extra costs.

SWOT: Threats
The proper operation and monitoring of SVE requires specific training and skills.

More information
http://www.frtr.gov/matrix2/section4/4-7.html

http://www.clu-in.org/download/remed/epa542r05028.pdf

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.4 Multi phase extraction (MPE)

Multi phase extraction is based on the driving remediation principle of extraction. MPE creates a near vacuum in the soil creating a flow of air, water and product layers to extraction wells. Wells for the MPE are installed just below the groundwater table. The extracted air and fluids have to be treated further depending on the levels of contamination and the risk related to the contaminants. Various techniques for air and water treatment exist and most of them can be implemented on-site.

Remediation level
The remediation level is very much depended on local conditions and contaminations. MPE should not be considered as a technique for the complete removal of contaminations or achieving low levels of residual contamination. In most cases MPE can successfully remove source areas of contaminations.

Technical risks
The permeability of the soil and the correct placement of MPE extraction wells in relation to the groundwater table are critical for the success of MPE. The risks can be very easy be controlled by implementing a pilot before deciding on the full scale application of MPE.

Costs
Operational costs of MPE are relatively low. Significant additional costs can be endured by the need for off gas, water and product treatment.

Sustainability
MPE is not a typically sustainable soil treatment technique. The main reason is the energy consumption of the technique.

Time
The time involved for MPE will always be in the range of ½ year - year.

Post remedial use
Soil treated by MPE is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
A MPE system results in little nuisances for its surroundings due to compact nature of the equipment. To minimize nuisance and odour issues, off gas treatment has to be applied if levels require so.

SWOT: Strengths
The strength of MPE is the ability to remove source areas of contamination in both the unsaturated and saturated zones of the soil. It also is successful in removal of product layers. MPE also stimulates the aerobic degradation in the unsaturated and saturated zone through the introduction of air. It also allows for additional techniques such as air-sparging, to be applied with little extra costs.

SWOT: Weaknesses
The application of MPE is limited to a small area of the soil. In most situations MPE has to be combined with extensive and expensive air and water treatment installations.

SWOT: Opportunities
The implementation of MPE allows for additional techniques such as air-sparging, to be applied with little extra costs.

SWOT: Threats
The proper operation and monitoring of MPE requires specific training and skills.

More information
http://clu-in.org/download/remed/mpe2.pdf

http://www.clu-in.org/download/remed/epa542r05028.pdf

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.5 Air sparging

Air sparging is based on the driving remediation principle of transformation
Air sparging involves the injection of atmospheric air beneath the groundwater table. The air volatilises the contamination from the groundwater and the soil. The air with the contamination subsequently rises up to the unsaturated zone where it is collected by a Soil Vapour Extraction system.

Air sparging can also be used as a technique to increase oxygen levels in the groundwater, the purpose being to enhance the aerobic degradation of contaminations. This application is referred to as bio-sparging.

Remediation level
The remediation level is very much depended on local conditions and contaminations and additional remediation systems. Air sparging is mostly combined with other techniques (Soil Vapour Extraction, groundwater abstraction).

Technical risks
The permeability of the saturated soil and the correct placement of air sparging injection wells in relation to the groundwater contamination are critical for the success of air sparging.

Costs
Operational costs of air sparging are relatively low.

Sustainability
Air sparging is not a typically sustainable soil treatment technique. The main reason is the energy consumption of the technique.

Time
The time involved for air sparging will mostly be limited to ½ year- year. Bio-sparging often requires a longer time due to the speed of the biological processes underlying the working of this technique.

Post remedial use
Soil treated by air sparging is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
An air sparging system results in little nuisances for its surroundings due to compact nature of the equipment.

SWOT: Strengths
The strength of air sparging is the ability of the technique to improve the performance of techniques as groundwater abstraction and soil vapour extraction.

SWOT: Weaknesses
Air sparging is not a standalone technique. In most situations additional techniques such as groundwater abstraction or Multi Phase Extraction have to be used during the remediation. An exception can be bio-sparging which can be used as a sole technique for the aerobic degradation for groundwater contamination.

SWOT: Opportunities
If properly designed, an air sparging can be easily transferred into a bio-sparging system. This enables the transfer to a bioremediation of the groundwater for organic components that are biodegradable under aerobic conditions.

SWOT: Threats
The operation of air sparging without proper monitoring of the technique can result in uncontrolled spreading of contamination.

More information
http://www.clu-in.org/download/citizens/a_citizens_guide_to_soil_vapor_extraction_and_air_sparging.pdf

http://dec.alaska.gov/spar/csp/guidance/guide_vapor.pdf *http://www2.bren.ucsb.edu/~keller/courses/esm223/SuthersanCh04AirSparge.pdf*

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.6 Soil heating

Soil heating is based on the driving remediation principle of transformation. The technique operates under the principal that electrical current passing through a resistive component, such as soil, will generate heat. Another option is to inject steam in the soil matrix. As a result the temperature of the soil will increase. This influences the mobility of many contaminants so that recovering them from the soil is made much easier.
Due to the temperature increase, the biodegradation of contaminants in the soil will also be enhanced. Soil heating allows for temperature increase from 20 to 100 Celsius.

Remediation level
The remediation level is very much depended on local conditions and contaminations and additional remediation systems for recovery. Soil heating can achieve high remediation levels for the saturated soil under optimal conditions. However it should be considered as a technique that can successfully remove source areas of contaminations.

Technical risks
The conductivity of the soil for electrical currents is critical for the temperature increase that can be achieved by soil heating. Also the free transfer of contaminants to extraction systems for recovery has to be determined in an early stage.

Costs
Operational costs of soil heating are relatively high.

Sustainability
Soil heating is not a typically sustainable soil treatment technique. The main reason is the energy consumption of the technique.

Time
The time involved for soil heating will mostly be limited to a month - ½ year. Additional techniques for the extraction of the contaminants will be required a longer time.

Post remedial use
Soil treated by soil heating is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
Soil heating systems result in little nuisances for its surroundings due to compact nature of the equipment.

SWOT: Strengths
The strength of soil heating is the ability of the technique to improve the properties of the soil and contaminants so that the performance of techniques as groundwater abstraction and soil vapour extraction are improved significantly.

SWOT: Weaknesses
Soil heating is not a standalone technique. In most situations additional techniques such as groundwater abstraction or soil vapour extraction have to be used during the remediation.

SWOT: Opportunities
Soil heating is very suitable for enhancing biodegradation.

SWOT: Threats
The operation of soil heating without proper assessment of its application beforehand can result in uncontrolled processes in the soil and high cost levels.

More information
http://www.epa.gov/superfund/remedytech/tsp/download/heatenh.pdf

http://www.clu-in.org/download/remed/sveenhmt.pdf

http://www.frtr.gov/pdf/in_situ_thermal_trtmnt.pdf

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.7 Elektrokinetics

Elektrokinetics remediation is an in-situ technique in which an electrical field is created in a soil matrix by applying a low-voltage direct current (DC) to electrodes placed in the soil. As a result of the application of this electric field, heavy metal contaminants may be mobilized and concentrated at the electrodes, and extracted from the soil. The application of the electric field has several effects on the soil, water, and contaminants. Cations (positively charged ions) tend to migrate towards the negatively charged cathode, and anions (negatively charged ions) migrate towards the positively charged anode. The application of the technique is focussed at heavy metals contaminations and some organic contaminations.

Remediation level
The remediation level is very much depended on local conditions and the type of contaminant.

Technical risks
The conductivity of the soil for electrical currents is critical

Costs
Operational costs of elektrokinetics are relatively high.

Sustainability
Elektrokinetics is not a typically sustainable soil treatment technique. The main reason is the energy consumption of the technique.

Time
The time involved for elektrokinetics will mostly be limited to ½ year – year.

Post remedial use
Soil treated by elektrokinetics is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
Elektrokinetics systems result in little nuisances for its surroundings due to compact nature of the equipment.

SWOT: Strengths
The strength of elektrokinetics is that this technique is able to in-situ remediate heavy metals.

SWOT: Weaknesses
Elektrokinetics is most often limited to small areas/volumes of contamination. Its application should be well evaluated beforehand as local conditions strongly influence the success of a full scale application.

SWOT: Opportunities
Elektrokinetics is very suitable for a target remediation of small, isolated heavy metal contaminations.

SWOT: Threats
The operation of elektrokinetics without proper assessment of its application beforehand can result in uncontrolled processes in the soil and high cost levels.

More information

http://www.frtr.gov/matrix2/section4/4-4.html

http://www.epa.gov/tio/download/remed/electro.pdf

http://www.epa.gov/superfund/remedytech/tsp/download/heatenh.pdf

4.8 In-situ chemical oxidation (ISCO)

ISCO involves the introduction of a chemical oxidant into the soil for transforming groundwater or soil contaminants in the saturated zone into less harmful chemical components. There is a variety of oxidants which can be used for ISCO, all possessing specific qualities for the remediation of a wide variety of contaminants.

Remediation level
The remediation level is very much depended on local conditions and the type of contaminant. ISCO is most suited to remediated source areas.

Technical risks
Oxidation chemicals are often non selective towards contaminants. Reactions with other organic components in the soil will compete with the oxidation of the contaminants. The selection of the appropriate oxidant is a very important step in minimizing risks.

Costs
Operational costs of ISCO are related to the amount and type of oxidizing agent required. In general, the costs are considered to be low.

Sustainability
Oxidation is not a typically sustainable soil treatment technique. The main reason is the energy consumption for the preparation of the oxidants.

Time
The time involved for ISCO is limited to 1 month - ½ year.

Post remedial use
Soil treated by ISCO is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
ISCO systems result in little nuisances for its surroundings due to compact nature of the equipment.

SWOT: Strengths
The strength of ISCO is the wide variety of contaminants that can be remediated.

SWOT: Weaknesses
ISCO is a non selective remediation process. The oxidizing agent will also react to non-hazardous components in the soil.

SWOT: Opportunities
ISCO is suitable for remediating source areas and plume areas of contaminations.

SWOT: Threats
The application of oxidants for ISCO is often based on overkill. Too much oxidant is applied resulting in unexpected and unwanted reactions.

More information

http://info.ngwa.org/gwol/pdf/101184365.pdf

http://www.epa.gov/ada/gw/isco.html

http://citychlor.eu/sites/default/files/code_of_good_practice_isco.pdf

http://www.soilpedia.nl/Bikiwiki%20documenten/SKB%20Cahiers/ISCO%20-%20In%20situ%20chemische%20oxidatie%20(Engels).pdf

http://www.epa.gov/superfund/remedytech/tsp/download/heatenh.pdf

4.9 Permeable Reactive Barriers (PRB)

A Permeable Reactive Barrier (PRB) is an engineered treatment zone of reactive material(s) that is placed in the soil in order to remediate contaminated groundwater as it flows through it. PRBs can be designed to treat a variety of groundwater contaminations and are most often used to remediate contaminated groundwater within aquifers. The reactive media used in PRBs enhances the chemical or biological transformation of the contaminant, or retards its migration by sorption or immobilisation of the contaminant onto the reactive media.

Remediation level
PRB's can achieve high remediation levels for the contaminants in the groundwater. Please note that when a source area of contaminations is present, the PRB this not influence the levels in this source area.

Technical risks
PRB's are dependent on the flow of groundwater through the barrier to accomplish the remediation. During the design of the barrier a thorough knowhow of the hydrological conditions is required. Also the resistance of the reactive material used in the barrier is critical for a good operation of the PRB. The selection of the appropriate reactive material is a very important step in minimizing risks.

Costs
The costs are governed by the installation of the PRB system. The depth and the size of the barrier and the fill material determine the costs. Operational costs of PRB's are low.

Sustainability
PRB's are considered to be a sustainable remediation technology. The energy consumption is very low (sometimes required for producing the reactive material). However, a PRB does not provide a definitive solution for a source area of contamination.

Time
The time involved for PRB installation is mostly limited to one month. The operational remediation time is dependent on extend of the groundwater contamination. The average time lies between 10- 20 years.

Post remedial use
Groundwater treated by PRB's is typically reusable.

Social criteria
The installation of a PRB can result in nuisances for its surroundings. During the operation of the PRB, very little nuisance is encountered.

SWOT: Strengths
The strength of a PRB's is the high remediation levels that can be achieved, the very low operational costs and the long term working of the system. PRB's can remediate a wide variety of contaminants.

SWOT: Weaknesses
PRB's require solid know how on hydrological conditions of the area. These conditions can change during the life time of the PRB. PRB's do not provide a permanent remediation solution for a source area of a contamination.

SWOT: Opportunities
PRB's are a sustainable alternative to pump & treat for aquifer contaminations.

SWOT: Threats
PRB's require a high quality monitoring of the system and the surrounding areas. During the long term a PRB is in operation, changes in hydrological conditions can occur.

More information

http://www.epa.gov/ada/gw/prb.html

http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/scho0902bitm-e-e.pdf

http://www.clu-in.org/download/citizens/a_citizens_guide_to_permeable_reactive_barriers.pdf

http://clu-in.org/download/rtdf/prb/reactbar.pdf

http://www.itrcweb.org/GuidanceDocuments/PRB-5-1.pdf

http://www.frtr.gov/matrix2/section4/4-53.html

http://www.frtr.gov/pdf/2-prb_performance.pdf

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.10 In-situ bioremediation

Organic contaminations are subject to biological degradation. Over time, levels of these contaminations will decrease. However, the rates in which the levels decrease are often very slow and not useful when considering remediation options. Bioremediation is aimed at accelerating biological processes. Key in

bioremediation is the identification and removal of the limiting factors for biological processes.
There is a large range of bioremediation techniques. They all have in common the use of biological processes for the degradation of contaminants. This is done by methods ranging from injecting nutrients to introducing suitable bacteria for the required degradation process.
Biological processes can thrive is saturated areas of the soil as biological processes need moisture to develop. Application of bioremediation is therefore most suitable for the saturated zone of the soil.

Remediation level
Bioremediation can achieve very low remediation levels. However this requires a very long period of time and homogeneous types of contamination. In general, bioremediation can eliminate risks related to contaminants.

Technical risks
Bioremediation requires a thorough understanding of all aspects influencing the biological degradation of a specific contaminant on a site. Apart from knowledge on contaminations, information on hydrological conditions, macro chemical composition of the groundwater and indigenous bacteria populations is required. Use of laboratory experiments to design full scale remediation for a specific site will result in disappointing remediation results.

Costs
The operational costs of bioremediation in general are low.

Sustainability
Bioremediation is considered to be a sustainable remediation technology. The energy consumption is very low.

Time
The time involved for bioremediation is typically between 1 and 5 years.

Post remedial use
Groundwater treated by bioremediation is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
Bioremediation techniques can result in nuisances for its surroundings during installation of nutrients etc. During the operation of the bioremediation, very little nuisance is encountered.

SWOT: Strengths
Bioremediation is a technique which uses the natural process of degradation for remediation purposes. Bioremediation can remediate a wide variety of organic contaminants.

SWOT: Weaknesses
Bioremediation requires a lot of specific investigations on items not common within the soil investigation and soil remediation. Also, remediation contractors are patenting various nutrient compositions limiting their use.

SWOT: Opportunities
Bioremediation is very suitable for contaminated sites where there are no time restrictions.

SWOT: Threats
Bioremediation requires a high quality of investigation data and monitoring.

More information
http://www.epa.gov/superfund/remedytech/tsp/download/issue11a.pdf

http://hazenlab.utk.edu/files/pdf/2009Hazen_HHLM_In_situ_groundwater_bioremediation.pdf

http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3065.pdf

4.11 Phyto remediation

Phyto remediation uses the property of some plants to absorb and store large amounts of mainly heavy metals in their roots and shoots. The technique involves selecting and cultivating plants that are suitable for the local soil and climate in which a contaminated site is located. After completion of a growth cycle or the remediation, the plants roots and shoots should be removed and properly be disposed.
Phyto remediation can be used for several purposes, ranging from the extraction of the heavy metals from the soil to preventing erosion and dispersion of the contaminated soil. Phyto remediation is generally limited to the immediate zone of influence of the roots. It is also possible to use phyto remediation to reduce levels of contaminants in the groundwater which are influenced by the root system of the plants.

Remediation level
Phyto remediation is not only targeted for extraction of contaminants from the soil. Often it is used to immobilize or contain a contamination. As such it is difficult to refer to a specific remediation level.

Technical risks
Phyto remediation requires a long preparation time in order to decide on the most suitable type of plant for the site and the contaminants. If this information is not available and/or not used for the design of the remediation, it is unlikely that phyto remediation will be successful.

Costs
The operational costs of phyto remediation in general are low.

Sustainability
Phyto remediation is considered to be a sustainable remediation technology.

Time
The remediation time is strongly related to the purpose of the phyto remediation. When applied for containment, the phyto remediation will be in operation for several decades. The time involved for phyto extraction is typically between 3 and 15 years.

Post remedial use
Sites treated by phyto remediation are typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
Phyto remediation often requires the remediation site to be closed off. As the remediation process will last a significant time, this can pose a significant hinder. During the operation of the phyto remediation, very little nuisance is encountered.

SWOT: Strengths
Phyto remediation is very well suited to remediate large areas impacted with shallow contaminations. The plants used for phyto remediation enhance the green appearance of a site, making a remediation less disturbing. If well designed, phyto remediation can remediate a wide variety of contaminants.

SWOT: Weaknesses
Phyto remediation requires a lot of specific investigations on items not common within the soil investigation and soil remediation (climate, plant growth). Also, the remediation time for the process is significant.

SWOT: Opportunities
Phyto remediation is very suitable for contaminated sites where there are no time restrictions on remediation and no urgent land use. Future genetic engineering will likely further improve the efficiency of the process.

SWOT: Threats
Phyto remediation requires a high quality of investigation data before starting the actual remediation. The uncontrolled disposal or use of plants which are used for phyto remediation, poses a serious risk.

More information
http://www.clu-in.org/download/citizens/a_citizens_guide_to_phytoremediation.pdf

http://www.nature.com/scitable/knowledge/library/phytoremediation-17359669 http://www.ecolotree.com/pdf/introphyto.pdf

4.12 Natural attenuation (NA)

Organic contaminations in groundwater are subject to processes such as biological degradation, dilution and diffusion. Over time these processes will result in a decrease of contamination levels or a halt to spreading of the contamination. Natural attenuation (NA) or Monitored natural attenuation uses these processes in a controlled manner for remediation purposes.

Natural attenuation is most often applied as an approach for managing residual contaminations in the groundwater.

Essential for the implementation of NA is a complete understanding of the contamination. Delineation of the contamination and modelling of future spreading all should be completed before starting NA. For most sites, NA can only be implemented after the source of the contamination is removed. Proper monitoring of the process and contaminant behaviour is an essential aspect of NA.

Remediation level
Natural attenuation can achieve low remediation levels. However this requires a very long period of time. The focus of natural attenuation is most often the control of risks related to spreading of a contaminant in the groundwater.

Technical risks
Natural attenuation requires a thorough understanding of all aspects influencing the behaviour of a specific contaminant on a site. Apart from knowledge on the contaminant, information on hydrological conditions, macro chemical composition of the groundwater and indigenous bacteria populations is required. A major contribution in reducing the risks is the use of conceptual site models (CMS) to assess risk related to the contamination. To predict future behaviour of the contaminant, hydrological models are valuable tools.

Costs
The operational costs of natural attenuation in general are very low. In the designing process, significant costs can be endured as a result of the thorough research that is required.

Sustainability
Natural attenuation is considered to be a sustainable remediation technology.

Time
The time involved for natural attenuation is typically between 10 and 25 years.

Post remedial use
Groundwater managed by natural attenuation is typically reusable in less sensitive uses as non-residential and non-agricultural uses.

Social criteria
Natural attenuation can result in nuisances for its surroundings due to the long time a contaminated site or the contaminated groundwater is not available for other uses. Natural attenuation itself consists mainly of monitoring which results in very little nuisance.

SWOT: Strengths
Natural attenuation is a technique which uses the natural processes occurring in the soil for remediation purposes. As such it is a very robust approach.

SWOT: Weaknesses
Natural attenuation requires a long time. The quality of project management and monitoring tends to suffer over this long time.

SWOT: Opportunities
Natural attenuation is very suitable for contaminated sites where there are no time restrictions. It is a very easy to adopt as part of a remediation scheme where source areas are removed.

SWOT: Threats
Natural attenuation requires a high quality of investigation well in advance of implementing the process. Restrictions on site use or groundwater use are sometimes difficult to enforce over the long period of time natural attenuation requires.

More information
http://www.clu-in.org/download/Citizens/a_citizens_guide_to_monitored_natural_attenuation.pdf

http://www.clu-in.org/download/remed/chl-solv.pdf

http://www.clu-in.org/download/remed/pet-hyd.pdf

http://www.nj.gov/dep/srp/guidance/srra/mna_guidance_v_1_0.pdf

http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3065.pdf

http://www.soilection.eu/index.php?option=com_technics&Itemid=26

4.13 Immobilization by in-situ vitrification

In-situ vitrification is a technique which focuses on the immobilization of contaminants. Vitrification is the process to make glass out of something, in relation to contaminated soil, to turn the soil containing the pollutant into a large block of glass. After the vitrification, the contaminant can then be left in place indefinitely encased inside of the glass without any risk of emissions.

Contaminants react in different ways to this remediation technique. Organic pollutants are pyrolyzed and are generally reduced into gasses. The gasses rise to the surface where they are collected by a gas hood over the subject site. The gases are then transported to an off-gas treatment system. The inorganic pollutants or heavy metals are encased in the glass formed by the vitrification process. Radioactive materials are also encased in the glass and the glass formed by the soil also helps to limit the radiation leakage. During the molten phase of the process almost all of the void spaces in the soil are removed and therefore there is a volume reduction of 20-50% of the original soil volume. The end result is a very dense block of glass.

Remediation level
As such no remediation levels are reached. However, all contaminants are encapsulated and no risks related to the original contamination endure.

Technical risks
Key in assessing the possibilities for vitrification is the composition of the soil. Good insight is required in percentage of organic constitutes of the soil. A to high percentage poses a high risk for vitrification. Also the amount of combustible contaminants should be well established beforehand otherwise uncontrolled explosions can result from the heating process.

Costs
The operational costs of vitrification are high. The costs are mainly related to the expensive equipment for the vitrification process and energy costs for the operation of the process.

Sustainability
Vitrification is not considered to be a sustainable remediation technology due to its high energy consumption. Also it renders the treated soil useless for any natural use.

Time
The time involved for in-situ vitrification is limited to 1-4 weeks, depending on the volume of soil to be remediated.

Post remedial use
Soil treated by vitrification in general possesses no qualities associated with natural soil.

Social criteria
Vitrification can result in significant nuisances for its surroundings due to the fact that the treated soil cannot fulfil any natural functions.

SWOT: Strengths
Vitrification can remediate specific contaminations that cannot be remediated by any other technique. As such it is a unique technology.

SWOT: Weaknesses
Vitrification will always be limited to a very specific group of contaminations. It is only feasible for the remediation of limited amounts of soil.

SWOT: Opportunities
Vitrification is very suitable for a target remediation of small, specific contaminations.

SWOT: Threats
Vitrification requires a high quality of investigation, staff and equipment. Restrictions on soil use after completion are significant.

More information

http://www.clu-in.org/download/contaminantfocus/dnapl/Treatment_Technologies/engineering_bulletin.pdf

http://www.wmsym.org/archives/2003/pdfs/460.pdf

4.14 Immobilization by in-situ grouting

In-situ grouting is a technique which focuses on the immobilization of contaminants. To achieve this, the contaminated soil is mixed or injected with an immobilizing component (the 'grout'). The injecting or mixing is carried out by vertical methods, mainly special drilling or injecting equipment. The grouting material used is depended on the site, the required immobilizing properties for the contamination and the soil conditions. Most often a type of cement or clay is used.

Remediation level
As such no remediation levels are reached. However, all contaminants are immobilized and no risks related to the original contamination endure.

Technical risks
Key in assessing the possibilities for in-situ grouting is the composition of the soil and contamination type. Application of grouting in low permeability soils is problematic as the grout material will not penetrate sufficient in the soil to immobilize all contaminants. For soils with a very high permeability, the grout material has to be amended with filler.
Certain types of grout can result in significant changes of soil volume.

Costs
The operational costs of in-situ grouting differ according to depth and size of the site to be treated. Also the specifics of the grouting material are of major influence to the costs.

Sustainability
In-situ grouting is considered to be a less sustainable remediation technology mainly due to the fact that it renders the treated soil useless for any natural use.

Time
The time involved for in-situ grouting is limited to a few weeks, depending on the volume of soil to be treated.

Post remedial use
Soil treated by in-situ grouting in general possesses no qualities associated with natural soil.

Social criteria
In-situ grouting can result in significant nuisances for its surroundings due to the fact that the treated soil cannot fulfil any natural functions.

SWOT: Strengths
The strength of in-situ grouting is the ability to stop all the leaching from contaminants. The technique can be applied to an extensive range of contaminants by changing the grout material qualities.

SWOT: Weaknesses
In-situ grouting will always be limited to a very specific group of contaminations and site locations. It is only feasible for the remediation of limited amounts of soil.

SWOT: Opportunities
In-situ grouting is very suitable for a target remediation of small, specific contaminations.

SWOT: Threats
In-situ grouting requires a high quality of investigation, staff and equipment. The assessment of the type grout required is an essential step. Restrictions on soil use after completion are significant.

More information
http://web.engr.oregonstate.edu/~hambydm/papers/remedrev.pdf

http://www.inl.gov/technicalpublications/Documents/3314427.pdf

http://www.frtr.gov/matrix2/section4/4-8.html

4.15 Vertical wall

The instalment and maintaining of a vertical wall is a technique which is aimed at control or containment of contaminated soil. The wall has impermeable qualities to prevent the spreading of contaminants or exposure to contaminants. The wall also prevents the inflow from clean water into the contaminated soil. Often, the vertical wall is combined with measures which prevent infiltration rainwater in the contaminated soil.
Vertical walls are systems widely used for general construction purposes. Their application for soil remediation requires however a specific quality focusing much more on retaining the contamination. Basic examples of vertical wall

include steel sheet piling and slurry walls. The most effective application of the vertical wall for site remediation is to base the wall into a low permeability layer such as clay or bedrock.

Remediation level
As such no remediation levels are reached. However, all contaminants are contained and no risks related to the contamination endure.

Technical risks
A vertical wall should contain the contaminants under all circumstances. Key in assessing the possibilities for a vertical wall is knowledge on the composition of the contaminants and their chemical properties which may affect the material of the wall and the hydrological conditions of a site. A solution can be to select a wall consisting of two materials such as betonite slurry in combination with a HDPE liner.
A major risk is the permeability of the wall. The material and the construction of the wall have to be guaranteed for a long time.

Costs
The costs of vertical walls are decided by the depth and the total length of the wall. Significant additional costs can be involved in the hydrological control (no infiltration on the soil) of the contained soil.

Sustainability
Vertical walls are considered to be a less sustainable remediation technology mainly due to the fact that it provides no definitive solutions for the contaminated soil.

Time
The time involved for the instalment of a vertical wall is fully dependent on the size of the wall. A good indication of required time is 1-6 months. After instalment the proper functioning of the wall have to be verified indefinitely.

Post remedial use
Soil contained by and vertical wall in general possesses no qualities associated with natural soil or with normal soil use. Under certain conditions the top layer of the soil contained by the wall, can be restored and used for basic, low sensitive purposes such as car parks, recreational areas or city parks.

Social criteria
The instalment of vertical walls results in significant nuisances for its surroundings. If the top layer of the site is not restored, the site cannot fulfil any functions for the area and is likely to become an unattractive area.

SWOT: Strengths
The strength of a vertical wall is the ability to stop all the leaching from contaminants to the surrounding area. The technique can be applied to an extensive range of contaminants and soil types.

SWOT: Weaknesses
Vertical walls require indefinitely control and management on the quality of the system.

SWOT: Opportunities
If well constructed and social needs are well integrated into the design process, vertical wall can contribute to the restoration of an area. Good examples include the construction of city parks on top of sites contained by vertical walls.

SWOT: Threats
The most significant threat to vertical walls is the long term functioning of the system. If no proper quality management is carried out during installation and maintenance, leakages from contamination through the wall are likely. Most important reason for leakage is infiltration of water into the site due to precipitation. The increase in water level and associated pressure to the wall is major threat.

More information
http://www.frtr.gov/matrix2/section4/4-53.html

4.16 Capping layer

The instalment and maintaining of a capping layer is a technique which is aimed at control or containment of contaminated soil or waste material. Capping layers form a barrier between waste or contaminated soil and the environment.
Capping layers also prevent the migration of contaminants from the site. This migration can be caused by rainwater or surface water moving over or vertically through the site, or by the wind blowing over the site.
Capping layers are generally constructed of clean sediment, sand, or gravel. A more complex layer can include geotextiles, liners, and other permeable or impermeable materials in multiple layers. Layers can also include additions of organic carbon or other in systems which control the movement of contaminants through the layer.
Capping layers can be applied for contaminated land but also for contaminated sludge or sediments in aqueous environments.

Remediation level
As such no remediation levels are reached. However, all contact and exposure to the contaminants is prevented by the layer.

Technical risks
A capping layer must protect the environment form the contaminants, must also be easy to be maintained and should last very long. To achieve all these functions, all issues that influence these qualities must be known before construction. Most common risks include the permeability of the cap, unexpected settling and consolidation of the soil which tears the cap.

Costs
The costs of capping layers are decided by the complexity of the structure and the area to be covered. Significant additional costs will be endured if active extraction systems (for gas and / or water) are required.

Sustainability
Capping layers are considered to be a less sustainable remediation technology mainly due to the fact that it provides no definitive solutions for the contaminated soil.

Time
The time involved for the instalment of a vertical wall is fully dependent on the area to be covered and the complexity of the system. A good indication of required time for simple application is time is 2 months. Complex capping layers can require 1 month/hectare area covered.
After instalment the proper functioning of the capping layer has to be verified indefinitely.

Post remedial use
Soil contained under the capping layer in general possesses no qualities associated with natural soil or with normal soil use. For capping layers used in an aqueous environment, the soul used for the capping layer often can support basic aquatic life.

Under certain conditions the capping layer can be an integral part of a new development and area used for basic, low sensitive purposes such as car parks, recreational uses or city parks.

Social criteria
The instalment of a capping layer results in significant nuisances for its surroundings. If no further development of the capping layer is undertaken, the site cannot fulfil any functions for the area and is likely to become an unattractive area.

SWOT: Strengths
The strength of a capping layer is the ability to stop all infiltration of precipitation or weathering of the contaminants thus preventing spreading. Capping layers also prevent any exposure to the contaminated soil.
The technique can be applied to an extensive range of contaminants, soil and waste types.

SWOT: Weaknesses
Capping layers require indefinitely control and management on the quality of the system.

SWOT: Opportunities
If well constructed and social needs are well integrated into the design process, capping layers can contribute to the restoration of an area. Good examples

include the construction of city parks on top of former waste dumps, indoor ski centres etc.

SWOT: Threats
The most significant threat to capping layers is the long term functioning of the system. If no proper quality management is carried out during installation and maintenance, damage of the capping layer is likely.

More information
http://www.clu-in.org/contaminantfocus/default.focus/sec/sediments/cat/Remediation/p/1/

4.17 Geohydrological control

The instalment and operation of a geohydrological control system is a technique which is aimed to control the spreading of contaminated groundwater.
The system prevents the migration of contaminants from the site. This migration is mostly caused by natural hydrological conditions. For most sites the systems requires various methods for the abstraction of groundwater and systems for the treatment of the groundwater. In some selected sites, plants can perform abstraction of the groundwater. This application of phyto remediation is sustainable alternative to abstraction for a geohydrological control system.

The technical approach for a geohydrological control system has a lot off similarities with a ground water abstraction – water treatment system (‘pump & treat’).

Remediation level
As such no remediation levels are reached. However, all spreading by the natural groundwater flow is prevented by the system. Risks related to spreading are stopped.

Technical risks
When considering a geohydrological control system, a thorough knowhow on the hydrological conditions on the site is essential. A misunderstanding of these conditions is the paramount risk when designing and operating a geohydrological control system. It can result in placement of abstractions systems in the wrong locations or systems which do not have the required capacity.

Costs
The costs of a geohydrological control are almost fully decided by the requirement to have a water treatment system. If a water treatment is required, costs are likely to be high. If this requirement does not exist, costs are low and mainly related to power costs for pumps and overall maintenance.

Sustainability
A geohydrological control system is considered to be a less sustainable remediation technology mainly due to the fact that it provides no definitive solutions for the contaminated soil. Also the abstraction of large quantities of

groundwater from the soil is not considered to be sustainable. Improvements can be made if the abstracted groundwater can, after treatment, be used for other purposes.

Time
The time involved for the instalment of a geohydrological control system is on average a few months. After start up, the system has to be operated indefinitely including monitoring of the hydrological conditions in the soil.

Post remedial use
Groundwater controlled by the system in general possesses no qualities associated with natural or normal use.

Social criteria
The instalment of a geohydrological control system results in little nuisance for its surroundings. Groundwater abstractions in general can result in nuisances for its surroundings due to lowering of the groundwater table and related geotechnical consequences (soil settling).

SWOT: Strengths
A geohydrological control system provides a fast solution for uncontrolled spreading of groundwater contamination. The basics of the system are simple and, if well designed, are not prone to technical difficulties.

SWOT: Weaknesses
Geohydrological control systems require indefinitely control and management on the quality of the system and the hydrological conditions on the site.

SWOT: Opportunities
The abstracted and treated groundwater can be used locally for various purposes.

SWOT: Threats
The use of groundwater abstraction can result in the loss of valuable water and depletion of water bearing layers.

More information
http://www.clu-in.org/download/citizens/a_citizens_guide_to_pump_and_treat.pdf

http://www2.bren.ucsb.edu/~keller/courses/esm223/SuthersanCh11Pump&Treat.pdf

4.18 Land use restrictions

Land use and activity restrictions for a site are implemented to eliminate exposure pathways for, or reduce potential exposures to contaminated land. Land use restrictions are temporary safety measures in preparation for more definitive remediation measures.

First step in considering land use restrictions is the identification of all activities which should not occur on the site unless further evaluation and remedial action is undertaken. These activities and uses may result in the exposure of persons or ecological receptors to the contamination.
After these steps are identified, the implementation of land use restriction is both technical and administrative. Technical implementation is very simple and can be sometimes limited to the installation of a fence to prevent people entering the site.

Remediation level
As such no remediation levels are reached. However, exposure to contaminants is prevented.

Technical risks
Land use restrictions are very simple techniques and measurements. The basis is understandings of the area were the restrictions should be applied and which restrictions are relevant. To make these decisions a good understanding of the contaminants and the exposure pathways is required.

Costs
The costs of the technical implementation of land use restrictions are low. Fencing and proper signalling in combination with regular monitoring and maintenance make up the technical costs. If the site is occupied and used by people it may be necessary to find alternative accommodation, resulting in significant additional costs.

Sustainability
Land use restrictions cannot be considered to be sustainable remediation technology mainly due to the fact that it provides no definitive solutions for the contaminated soil.

Time
The time involved for installing proper fencing etc. is limited. After the restrictions are implemented they have to be maintained and monitored until a definitive remediation is carried out.

Post remedial use
Land use restrictions seldom result in post remedial use of a site. If there are differentiations in restrictions, some uses may be allowed. However, they rarely have qualities associated with natural or normal use of the soil.

Social criteria
The instalment of land use restrictions can result in significant nuisance for people as they are likely not allowed to enter or use the site.

SWOT: Strengths
Land use restrictions are a fast solution for uncontrolled exposure to all types of contaminants. The basics of the system are simple and have low maintenance costs.

SWOT: Weaknesses
Land use restrictions can be very intrusive as the prevent persons from entering a specific site or area. The restrictions require indefinitely control and monitoring.

SWOT: Opportunities
Land use restrictions can have unexpected benefits for biodiversity as the site is not accessible by people.

SWOT: Threats
Land use restrictions can generate desolate areas which can negatively affect communities.

4.19 Relocation and safety measures

Relocations and safety measures are drastic methods for gaining control over risks related to contaminations. This approach is considered for large scale environmental problems affecting large areas. This method is applied when time is required to find definitive solutions for the contaminations; however it is likely that this will take decades. Examples of the application of this approach are former mining areas and radioactive contaminated areas.
The practical implication of relocations and safety measures implies removing all people from the affected area. Alternative housing has to be provided for those relocated. For the affected area, safety measures have to be enforced. They include access restrictions to the area and monitoring of most relevant spreading routes of the contamination.

Remediation level
As such no remediation levels are reached. However, human exposure to contaminants is prevented.

Technical risks
Relocations and safety measures are very simple techniques and measurements. The basis is understandings of the area were relocation has to be enforced and which type of safety measures is relevant. To make these decisions a good understanding of the contaminants and the exposure pathways is required.
It is without doubt that the social impact of the measures and possible resistance to the relocation is the most significant risk.

Costs
The costs of the technical implementation of land use restrictions are low. However, other costs will be significant. Relocation, finding alternative housing, compensation for those affected will result in very high costs.

Sustainability
Relocations and safety measures cannot be considered to be a sustainable remediation technology mainly due to the fact that it provides no definitive solutions for the contaminated soil.

Time
The time involved for the technical issues such as installing proper fencing etc. is limited. However, relocation of people and finding alternative living quarters for them will take a significant period. After relocation is implemented, safety measures have to be maintained and monitored until a definitive remediation is carried out. This is likely to be several decades.

Post remedial use
Relocations and safety measures seldom result in post remedial use of a site.

Social criteria
The relocations of people from an area will result in significant nuisance and is likely to encounter resistance from inhabitants of the area.

SWOT: Strengths
Relocations and safety measures are a drastic but working solution for the prevention of exposure to contaminants. The technical basics of the system are simple and have low maintenance costs.

SWOT: Weaknesses
Relocations and safety measures are very intrusive as it removes people from the area were they have their livelihood. The safety measures require indefinitely control and monitoring.

SWOT: Opportunities
Relocations and safety measures for an area can have unexpected benefits for biodiversity as the area is not accessible by people.

SWOT: Threats
Relocations can generate desolate areas which will negatively affect communities.

4.20 Drinking water treatment

Drinking water attained trough wells, surface water and piping can become contaminated. The processes that result in the contamination can be very different. Direct emissions of pollutants into surface waters, contamination of water bearing layers and penetration of contamination through piping are all known causes for affecting drinking water. As drinking water is an essential resource for life, the contamination of water will result in direct health problems. Drinking water treatment is focussed on providing alternatives for the contaminated resources. It can be implemented in various manners, ranging from drinking water delivery by trucks, to small treatment plants. In combination with these provisions for clean drinking water, the contaminated resources have to be shut off.

Remediation level
As such no remediation levels are reached. However, exposure to contaminated drinking water is prevented.

Technical risks
To provide alternative drinking water can be a very simple technique.
Without doubt the social impact of the measures is the most significant risk.

Costs
The costs for providing alternative drinking water can be high depending on site specific conditions and the presence of good alternatives.

Sustainability
Drinking water treatment cannot be considered to be a sustainable remediation technology. It is only meant to provide safe drinking water and does not in any way contribute to a definitive solution for the contaminated soil.

Time
The time involved for the installing alternatives for drinking water can be very short. After installing an alternative drinking water provision, the operation has to be maintained until a definitive restoration of the original drinking water resources has been completed.

Post remedial use
Drinking water treatment does not affect or enhance the post remedial use of a contaminated site.

Social criteria
Installing alternative drinking water treatment for an area can result in social tensions. People are shut off from their known sources of drinking water and will feel insecure.

SWOT: Strengths
The strength of this measure is that it immediately stops the exposure to contaminated water. The technical basics for alternative drinking water systems can be simple.

SWOT: Weaknesses
Installing alternative drinking water resources is very intrusive for people living in the area. It can only be considered as a measurement preceding a definitive remediation.

SWOT: Opportunities
Installing alternative drinking water resources can be the start of revising or implementing modern drinking water systems for an area.

SWOT: Threats
Drinking water is an essential resource. It is likely that a poor control on the alternative provision of drinking water can result in tensions.

4.21 Water treatment technologies

Water treatment technologies used for contaminated water flows are all related to existing industrial treatment technologies and water treatment plants.

Following treatment technologies are most common for application on remediation sites.

Activated Carbon
Activated carbon is widely used in water treatment plants. The principle of activated carbon is the absorption of the contaminant on the carbon. Activated carbon is mostly used for the treatment of VOC. However, other types of contamination can include some heavy metals. Activated carbon is a simple technology which can achieve high levels of treatment efficiency (90%).
At soil remediation sites activated carbon is mostly used for small water flows or as a second treatment step after air stripping.

Air Stripping – Shallow tray aeration treatment
Air stripping is the most widely used technology for water treatment for sites contaminated wit VOC. The contaminated water is generally pumped into a collection vessel where it pumped into spraying nozzles located in the top of the air stripping column. The water encounters ambient air from outside the stripper unit blown into the water with sufficient pressure to push the air up.
As the air flows upward through the water, contamination is transferred to the air flow. The stripped off gas air continues upward and is blown out the top of the air stripper unit for discharge to an additional post treatment (if required).

The shallow tray aeration treatment uses the same basic technology. Ambient air is blown through hundreds of holes in the bottom of the trays to generate a froth of bubbles. This results in a large mass transfer surface area where the contaminants are volatilized. The stripped off gas air is blown out the top of the unit for discharge to an additional post treatment (if required). The big advantage of a shallow tray system is the compact size.

Separation
Most widely used at soil remediation sites is the oil – water separator. It is a simple technique which separates oil from water. The basic principle is based on the difference in density. Water has a higher density then most hydrocarbons. In a settling vessel the oil will migrate to the top, forming a layer that can be separated from the water. The oil layer can be removed for separate treatment. Particles heavier then water will settle on the bottom allowing them also to be removed. This type of separation is mostly used to reduce levels of oil and remove floating particles from the water. This type of separation is very simple to operate.

A more completed method of separation is membrane filtration. This technology removes contaminants from water by passing the water trough a semi permeable barrier or membrane. The membrane allows some constituents to pass while it blocks others. This type of treatment can be used to remove heavy metals from water flows.

Precipitation
For this technique, chemicals are added to the water to transform the dissolved contaminants into insoluble solids or on which the dissolved contaminants will

be adsorbed. The insoluble solids are then removed from the water flow using clarification or filtrations. This type of treatment is often used to remove heavy metals from water flows.

Biological treatment
This type of technology is widely used in the treatment of waste water. It now forms the basis of wastewater treatment worldwide. It simply involves confining naturally occurring bacteria at very much higher concentrations in tanks. These bacteria, together with some protozoa and other microbes, are collectively referred to as ‘activated sludge’. The concept of treatment is very simple. The bacteria remove small organic carbon molecules by ‘eating’ them. As a result, the bacteria grow, and the wastewater is cleansed. Whilst the concept is very simple, the control of the treatment process is very complex, because of the large number of variables that can affect it. These include changes in the composition of the bacterial flora of the treatment tanks, and changes in the sewage passing into the plant. The influent can show variations in flow rate, in chemical composition and pH, and temperature.
Biological treatment is seldom used on-site at soil remediations. However, water emitted to the sewer system will be treated by this system is a waste water treatment plant is in operation.

Oxidation
Oxidation processes are an emerging technology that can be used for specific goals in wastewater treatment. Oxidation utilizes the very strong oxidizing power of hydroxyl radicals to oxidize organic compounds to the preferred end products of carbon dioxide and water. The type of oxidant has to be selected based on the contaminants to be treated. For water treatment, UV has fast becoming a very much used method for oxidation. This method is capable in handling almost all organic contaminants.

4.22 Off gas air treatment technologies

Various remediation technologies create contaminated gasses. Examples are soil vapor extraction and multi phase extraction. For the on-site treatment of these gasses, existing industrial technologies for off gas treatment are applied.

Following treatment technologies are most common for application on remediation sites.

Activated Carbon
Activated carbon is used in many industrial processes and consumer applications. The use in remediation technologies is not limited to off gas air treatment. It is also used in water treatment plants (water phase).
The principle of activated carbon is the absorption of the volatile contaminant on the carbon. Activated carbon is mostly used for the treatment of VOC’s.
The treatment efficiency is very high (>99%) for good quality activated carbon.

Bio filtration
Bio filtration is a method of transforming mainly hydrocarbons with the use of bacteria. The bacteria are specifically designed to digest the unwanted

hydrocarbon. These bacteria may be designed to work in conjunction with an activated carbon system. Bio filtration is suitable for low-medium high gas levels. If well designed and maintained, the treatment efficiency can reach 95%. The major benefit of a bio filtration system is the reduction in operating costs such as electricity and adsorption media. The maintenance is reduced due to fewer operating parts.

Thermal oxidation
Thermal oxidation is most often used to convert organic hydrocarbons into carbon dioxide and water. The principle is based on increasing the thermal temperature of the gas, breaking of the hydrogen-carbon bonds. This process allows new bonds to be created such as CO_2 and H_2O. As can be expected, these types of systems consume large amounts of energy. However, they can be interesting for off gas treatment of large, industrial type flows.

Catalytic Oxidizers
Catalytic oxidizers are alternatives to thermal oxidizers. These systems oxidize waste gas into CO_2 and H_2O. Their successful operation is limited to a more controlled range of applications and components than other thermal oxidizers. They are most suitable for hydrocarbons. Catalytic oxidizing systems have considerably lower fuel consumption, operating costs and lower CO and NO_x emissions.

4.23 Recovery of material from remediation activities

Contaminated sites possibly contain materials that may be valuable for reuse. So efforts can be justified to find out if these materials may be retrieved from these sites.

An important hindrance for reuse results from the mixing of the materials in soil. Due to this mixing, the materials are often difficult to extract from the soil matrix. In the soil matrix, potentially reusable materials have been mixed with other materials. So, is can be very difficult to produce pure materials from a remediation site. Because of this it is hard to find a useful industrial reuse purpose for the retrieved materials.

If these hindrances can be overcome, the recovery of materials can be a positive contribution to a remediation.

For (former) landfill sites many studies have been carried out on the possibilities for ‘waste mining’.
Recycling waste in many cases is technically achievable. Legal and financial aspects can be found to be restrictive for implementation of these techniques. However if the recovery of material can be part of a remediation strategy to remove the contaminated material and to redevelop the area it might be a cost efficient approach to consider.

In 2003 a paper on landfill mining in India was published (*Studies on landfill mining at solid waste dumpsites in India, J. Kurian et. al., article in the Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium*). Conclusion of this paper was that the concept of waste mining and related technology merits serious consideration in the rehabilitation of dumpsites. Site-specific conditions will determine whether or not landfill mining and reclamation is feasible for a given location. The key conditions to be considered include composition of the waste initially put in place in the landfill, historic operating procedures, extent of degradation of the waste, types of markets and uses for the recovered materials. The heavy metal content and other characteristics of the recovered soil fraction indicate that the fraction can be suitable for landfill cover material. The compost standards are met for most parameters in the soil fraction of most studies.

4.24 Remediation of contaminated sediments

For sediment remediation following basic principles apply:

- A contaminated sediment problem nearly always deals with huge volumes. So, the costs of appropriate treatment technologies are an important factor.
- Since sediments tend to be very heterogeneous, a selected treatment technology must able to cope with this aspect. This means that the technology has a low sensitivity to variations: if (slight) deviations in the presumed physical-chemical composition occur the treatment still does not fail.
- Mineral materials are basically appropriate as a building material. The utilization of treated sediments may contribute to the reduction of raw materials such as sand, rock and so on. Possible applications are dependent on the treatment technology used. Some applications include foundation material under roads and parking's, construction material in sound barriers and so on.

There are two generic ways to remediate contaminated sediments in surface water: contaminated sediments may be dredged and the material is treated of disposed of or the contaminated compounds in the sediments may be immobilized in-situ.

Dredging
In general terms, dredging technologies can be divided into three groups on the basis of their principle of operation: mechanical dredging technologies, hydraulic dredging technologies and technologies for work under special conditions. All dredging technologies for the removal of contaminated sediments should achieve a high level of accuracy and a minimum of spillage and turbidity. In addition efforts should be made to pick up as little water from the surroundings as possible. For this reason, much emphasis is placed on achieving as high a density mixture as possible in hydraulic dredging, and the highest feasible filling level of the excavator bucket in mechanical excavation. When designing the dredging operation, following elements need to be taken into consideration: type of surface water and water depth; current and waves; soil properties; type and amount of contamination; possible obstacles.

Treatment of dredged material
For treatment of dredged sediments, following techniques will be explained:

- Separation in sedimentation basins;
- Physical separation;

- Ripening;
- Biological decontamination;
- Immobilization;
- Dewatering and storage of sludge in tube made of geotextile;
- In-situ treatment of contaminated sediments.

Separation of dredged sediments in sedimentation basins
After the dredging the sediments are injected as slurry into the sedimentation basin. The slurry flows from the injection point to the effluent side, where the excess water and any suspended particles are removed from the basin. The coarse, sandy fraction is thus separated from the more contaminated mud fraction, using the differences in sedimentation behavior of the coarse heavy (sand) particles and fine light (clay) particles and of the fact that the contaminants generally attach themselves to the clay fraction.
A relatively clean sand fraction is produced by separating the coarse and fine particles from each other.

Physical separation
Sediment separation is based on physical properties. Particles are separated with the objective to obtain a large volume of "clean" material (which can be put to reuse) and a small concentrated amount of highly contaminated material which must be disposed of or will be treated further.

Most available technologies are capable of processing sediment which contains a sufficient amount of sand. The sandy fraction is generally not contaminated and can easily be purified further, if so desired. The contaminated residue can either be stored in a smaller space than the one claimed by the original integrated sediment, or be treated further.

Ripening of dredged sediment
Ripening is a natural process with physical, chemical and biological processes, in which the predominantly anaerobic dredging mud is converted into a more compact, better aerated, more permeable material by evaporation and oxidation. This process slowly converts the dredging mud from a wet slurry into a solid clayey soil. The volume of material is, depending on its initial dry-matter content and physical composition, reduced by 30-50%. Ripening is an irreversible process, i.e. the material does not revert back into its original state after re-wetting. The dredging mud is ripened to obtain an environmentally acceptable product that can be used for civil engineering works such as construction of dykes and roads.

Biological decontamination of dredging mud
The objective of the biological techniques is the removal of organic contaminants using bacterial degradation. Microorganisms (bacteria and fungi) can use certain organic contaminants for their growth and/or metabolic processes. However not all types of contaminants can be degraded, e.g. heavy metals. Based on the manner in which oxygen is introduced into the process, four biotechnological concepts can be distinguished: decontamination in-situ, in depots, in land farms and in reactors. Landfarming however is not a suitable technique in India due to agricultural policy.

Immobilization
Immobilization is here defined as the technical treatment to change the physical and / or chemical properties, to minimize spreading of contamination by leaching, erosion or drifting. The aim of immobilization (also called: solidification or stabilization technologies) is a stronger fixation of contaminants to reduce the emission rate to the biosphere and to retard exchange processes. Most of the stabilization technologies aimed for the immobilization of metal-containing wastes are based on additions of cement, water glass (alkali silicate), coal fly ash, lime or gypsum. Generally, maintenance of a pH of neutrality or slightly beyond favors adsorption or precipitation of soluble metals. Recently, the technology provides a better immobilization for organic contaminants.

Immobilization may be applied to the whole sediment or to the fines produced by the sediment separation. The source material is (highly) contaminated and the main parameter that has to be controlled is the leaching factor. Binders and additives are used to control the leaching. Often cement is used as a binder but some companies also use self developed secondary binders made from by-products of the industry. Depending on the type of contaminant additives are chosen. The “recipe” for these additions is dependent on the characteristics of the sediment.
The result of the immobilization will be a product that can be used as foundation material for road construction, parking lots etc.

Dewatering and storage of sludge in tubes made of geotextile
Dewatering of dredged material by using tubes made of geotextile is a method to reduce the amount of water in sludge. To improve the dewatering process specific chemicals may be added to bind the solid. After the water has been removed from the sludge the tube can be removed. Due to the fact that the volume has reduced the costs for further treatment are much lower than for the original volume. If the level of the contamination of the dewatered sludge is low and monitoring is applied the tubes may be used for civil engineering constructions.

In-situ treatment of contaminated sediments
The general purpose of this technique is to introduce substances in or on top of the sediments which result in limiting the availability of contaminants into the biosphere. A good example is the introduction of activated carbon in the top layer of the sediments. The activated carbon absorbs the contaminants and so prevents them from entering the biosphere.
A major disadvantage of in-situ treatment is the lack of control on the process. It is very difficult to assess if the technique achieves its goal. Also, the application the technique is limited to water bodies with little natural flow and traffic.

5 Menu of prioritized remediation options for (sub)types of contaminated sites

This Section presents a menu of most likely (‘prioritized’) options for remediation of (sub)types of sites (refer to Glossary). This Menu of remediation options provides a first indication of potential remediation options that may be suitable for the situation at hand. For small and simple sites one or more best practice methods included in the menu may directly apply. In more complex situations the best practice overview will help the performing agent to make the first steps in the development of options.

Table III-5.4.3 Overview of remediation options and their applicability to types of sites

Explanation example of how to read the table: a site of both S1 and P2 type, i.e. a site with both land bound solid phase contamination as well as groundwater contamination is described in the first and third line in the table. In case the site is in an industrial setting in an urban area you may refer to remediation option 3 in figure III-5.4.1.

Nr.*)	Type **)					Subtype				
	S1	S2	L	P1	P2	Land use (present)				Remark
Option						Ur-ban	Indu stry	Nature	Agricul-ture / rural	
1	X				X	X				
2	X(d)				X			X	X	
3	X				X	X	X			
4		X				X	X	X	X	
5	X(def)								X	
6	X							X		
7	X					X				
8	X						X			
9			X							
10				X			X			Type P1-a
11				X			X			Type P1-b
Additional options based on *clustering* of specific types										
12	X									‘Cluster sites’
13			X		X					Area oriented groundwater approach

Explanation:

X Types of sites for which a blueprint of options is presented in this Section

**) Number referring to remediation options presented in this Section:*

1. Type S1 + P2: Land bound solid phase contamination and groundwater contamination
2. Type S1-d + P2: Land bound solid phase contamination and groundwater contamination
3. Type S1 + P2: Land bound solid phase contamination and groundwater contamination
4. Type S2: Solid phase contamination (water bound site, open water sediments)
5. Type S1-d-e-f: Land bound solid phase contamination
6. Type S1: Land bound solid phase contamination
7. Type S1: Solid phase contamination (land bound site)
8. Type S1: Land bound solid phase contamination
9. Type L: Liquid phase contamination, both NLAPL and DNAPL
10. Type P1-a: Dense Non-Aqueous Phase Liquid (DNAPL) in permeable soil (bulk density > water)
11. Type P1-b: Light Non-Aqueous Phase Liquid (LNAPL) in permeable soil (bulk density < water)
12. Type S1-a/b: Cluster of land bound solid phase contamination
13. Type L1: Cluster of liquid phase contamination (multiple/overlapping plumes)

***) Type of contaminated sites(see Glossary)*

S1 Solid phase land bound contaminations
S2 Solid phase water bound contaminations
L Liquid phase contaminations
P1 Liquid phase related DNAPL / LNAPL contaminations
P2 Leached or dissolved contaminants

In figure III-5.4.1 (see next pages) each of the 13 remediation options mentioned in the table above is discussed. We present every option in the same format, one option to a page, each divided into four headings:

- Site and setting summary
  This heading presents a brief summary of the main site characteristics, i.e. type of contamination, setting and site use, most prolific risks and most common contaminants, always illustrated by a schematic cross-section.

- Most likely remediation objectives
  This heading presents recommendations for cleanup levels. Where applicable, examples are given of sensitive land use that may require additional evaluation as to whether remediation to the generic level for the corresponding land use will provide sufficient level of protection. In general, fit for use levels based on the corresponding type of land use are recommended. Setting generic levels as remediation goal may not always result in an economically or technically feasible remediation. In such cases remediation to a concentration level meeting a site specific level based on site specific risk assessment can be considered.

- Most likely remediation measures
  This heading lists the most likely remediation measures according to the targeted point of operation (source, pathway or receptor). It must be stressed that this heading should not be used as the only reference in the design process of remediation option. We refer to Chapter 5 for more information.

- Specific conditions or alternative approaches
  This heading describes specific conditions that may prove pivotal for cost efficient remediation design. Also listed are some alternative remediation options that may come into perspective in case the costs of full scale remediation to generic levels are not in balance with the required level of risk reduction. In specific cases alternative remediation options can be acceptable and viable, e.g. in case the costs render a full scale remediation not feasible, or in case these options are used as a temporary safety measure, or in case the Indian soil remediation policy offers opportunities for a decreased (site-specific) level of risk reduction.

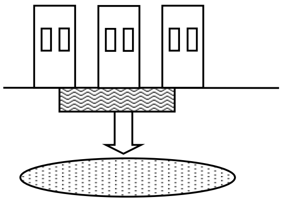
It should be noted that feedback from the Client and end users is crucial to determine whether or not to include the more creative remediation options in the Guidance document.

Figure III-5.4.1 Blueprint of options: most likely remediation measures per type of site (13 pages with figures)

Option 1: Remediation of land bound solid phase contamination including groundwater contamination in urban areas

Site and setting summary

Type S1 + P2: Land bound solid phase contamination including groundwater contamination
Setting: Urban area
Risks: Direct contact, exposure to polluted drinking water
Most common contaminant: heavy metals



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Top soil: fit for use based on generic levels for residential areas
- Groundwater: fit for use based on generic levels for residential areas

Examples of sensitive uses that may require site-specific remediation goals:
- Use of soil as kitchen garden or playground
- Use of groundwater as drinking water

Most likely remediation measures

Source
- Excavation of soil to a concentration level meeting the remediation objective
- Cover with pavement or layer of clean soil
- Reduction of leaching by partial source excavation, sealing or drainage

Pathway (plume):
- Removal to a concentration level meeting the remediation objective by pump & treat
- Vertical wall or geohydraulical containment
- Natural or stimulated precipitation/sorption

Receptor:
- Treatment of well water to meet drinking water standards or alternative water source
- Imposed limits to site use (e.g. no unauthorized digging, no wells)

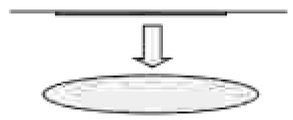
Specific conditions or alternative approaches

- Excavation is more efficient as part of a redevelopment project that involves excavating anyway
- Removal of contamination in pathway (plume) by pump & treat is more efficient if the leaching process has been reduced
- Soil surface elevation can be considered to avoid large volumes of excavated soil
- An alternative option to reduce contact risk and/or leaching may be chemical immobilisation or physical immobilisation (grouting)
- In-situ strategies towards hexavalent chromium are mostly based on reduction to the less toxic and less mobile trivalent chromium by chemical or microbiological means. These techniques are mostly in a laboratory or pilot phase of development

Option 2: Remediation of land bound solid phase contamination including groundwater contamination in agricultural and other rural areas

Site and setting summary

Type S1-d + P2: Land bound solid phase contamination including groundwater contamination
Setting: Agricultural or other rural area
Risks: Direct human contact, exposure to polluted drinking water, ingestion of contaminated crops
Most common contaminants: heavy metals, pesticides



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Top soil: fit for use based on generic levels for agricultural or other rural areas
- Groundwater: fit for use based on generic levels for agricultural or other rural areas

Examples of sensitive uses that may require site-specific remediation goals:
- Specific toxicity of copper to sheep
- Specific uptake of contaminants by crops
- Use of groundwater for irrigation purposes

Most likely remediation measures

Source:
- Phytoremediation
- Excavation of soil to a concentration level meeting the remediation objective, on-site treatment (landfarming) and optional backfilling with soil of suitable quality

Pathway (plume):
- Removal to a concentration level meeting the remediation objective by pump & treat
- Geohydraulical containment

Receptor:
- Treatment of well water to meet drinking water standards or alternative water source
- Alternative crops with less uptake of contaminants in edible parts
- Imposed limits to site use (e.g. no unauthorized digging, no wells)

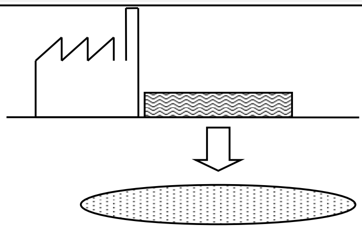
Specific conditions or alternative approaches

- Profile reversion can be considered as alternative approach
- Aggressive treatments like chemical treatments deteriorate the biology of the ground
- The cultivation method and climatic circumstances should also be taken into consideration when evaluating potential risk, cleanup levels and remediation, e.g.:
  - Erosion by wind and/or precipitation
  - Intensified contact with soil due to cultivation by manpower
  - Increased biodegradation rate due to tropical conditions
  - Promotion of anaerobic processes due to submerged cultivation methods
  - Cyclical changes in soil physical, macrochemical and biological properties due to slash and burn agricultural methods

Option 3: Remediation of land bound solid phase contamination including groundwater contamination in industrial areas

Site and setting summary

Type S1 + P2: Land bound solid phase contamination including groundwater contamination
Setting: Industrial area
Risks: Direct human contact, exposure to polluted drinking water
Most common contaminant: heavy metals



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Top soil: fit for use based on generic levels for industrial areas
- Groundwater: fit for use based on generic levels for industrial areas

Examples of sensitive uses that may require site-specific remediation goals:
- Use of groundwater as drinking water
- Use of groundwater as process water

Most likely remediation measures

Source
- Excavation of soil to a concentration level meeting the remediation objective
- Capping with pavement
- Combined with redevelopment: isolation under new buildings or constructions

Pathway (plume):
- Removal to a concentration level meeting the remediation objective by pump & treat
- Vertical wall or geohydraulical containment
- Natural or stimulated precipitation/sorption

Receptor:
- Treatment of well water to meet drinking water standards or alternative water source
- Imposed limits to site use (e.g. no digging, no wells)

Specific conditions or alternative approaches

- Removal of contamination in pathway (plume) by pump & treat is more efficient if the leaching process has been reduced
- Removal of contamination in pathway (plume) by pump & treat is more efficient if the treated water can be used as process water by the industry or when performed in combination with storage of thermal energy in soil
- Chemical or biological barriers can be considered on sites neighbouring more sensitive (e.g. urban) areas as alternative to full plume treatment
- Treatment of the actual cause of the pollution (industrial activity), if still present, should be performed before starting remedial action

Option 4: Remediation of solid phase contamination in a water bound site (contaminated open water sediments)

Site and setting summary

Type S2: Solid phase contamination (water bound site) (open water sediments) *Setting*: Urban, nature or industrial area *Risks*: Direct human contact, ecological risks *Most common contaminant*: heavy metals, effluents	 *Draft sketch of typical field situation*

Most likely remediation objectives

Recommendations for cleanup standards and levels
- Sediment: fit for use based on generic level corresponding with type of site use

Examples of sensitive uses that may require site-specific remediation goals:
- Use of open water for swimming or bathing
- Use of surface water for consumption or agricultural purposes

Most likely remediation measures

Source
- Dredging
- Excavation (in times of drought)
- Capping layer with clean sediment

Pathway (plume): n.a.

Receptor:
- Government imposed limits to site use (e.g. fencing, no bathing or swimming)

Specific conditions or alternative approaches

- Capping is only technically feasible for relatively static water systems (lake, pond)
- Dredging or excavation typically involves large volumes for which adequate (temporary) storage has to be provided, also depending on method of treatment (on-site treatment/off-site treatment/sanitary landfill)

Option 5. Remediation of land bound solid phase contamination in agricultural areas or open water shores

Site and setting summary

Type S1-d-e-f: Land bound solid phase contamination *Setting*: Agricultural area, open water shores *Risks*: Direct human contact, ingestion of crops, risk of spreading *Most common contaminant*: heavy metals, pesticides	*Draft sketch of typical field situation*

Most likely remediation objectives

Recommendations for cleanup standards and levels:
• Top soil: fit for use based on generic levels for agricultural areas

Examples of sensitive uses that may require site-specific remediation goals:
• Specific toxicity of copper to sheep
• Specific uptake of contaminants by crops

Most likely remediation measures

Source
• Phytoremediation
• Excavation and reuse in levees (open water shore settings) or big bags (fitted into the landscape)

Pathway (plume): n.a.

Receptor
• Alternative crops with less uptake of contaminants in edible parts

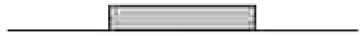
Specific conditions or alternative approaches

• Profile reversion can be considered as alternative approach
• Aggressive treatments like chemical treatments deteriorate the biology of the ground
• Specific excavation of hotspots can be considered as alternative approach, but requires detailed site assessment
• The cultivation method and climatic circumstances should also be taken into consideration when evaluating possible risk, cleanup levels and remediation, e.g.
  • Erosion by wind and/or precipitation
  • Intensified contact with soil due to cultivation by manpower
  • Increased biodegradation rate due to tropical conditions
  • Promotion of anaerobic processes due to submerged cultivation methods
  • Cyclical changes in soil physical, macrochemical and biological properties due to slash and burn agricultural methods

Option 6. Remediation of land bound solid phase contamination in nature areas

Site and setting summary

Type S1 : Land bound solid phase contamination
Setting: Nature area
Risks: Ecological risks, direct human contact
Most common contaminant: heavy metals



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels
• Top soil: fit for use based on generic levels for nature areas

Examples of sensitive uses that may require site-specific remediation goals:
• Intensive recreational use

Most likely remediation measures

Source
• Capping to reduce exposure by direct contact and vegetation consumption
• Phytoremediation to reduce concentration levels
• Excavation of hotspots

Pathway (plume): n.a.

Receptor
• Goverment imposed limits to site use (e.g. fencing, no unauthorized access)

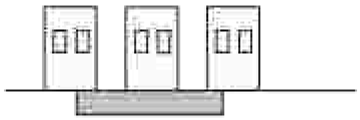
Specific conditions or alternative approaches

• Specific excavation of hotspots requires detailed site assessment
• To reduce the quantity of soil in excavation of hotspots, site-specific remediation levels higher than the generic levels for nature areas can be developed to obtain acceptable risk levels for a particular site under particular circumstances
• Capping can be combined with nature development (landscaping) to both increase environmental quality and biodiversity

Option 7: Remediation of land bound solid phase contamination in urban areas

Site and setting summary

Type S1: Land bound solid phase contamination
Setting: Urban area
Risks: Direct contact
Most common contaminant: heavy metals, PAH



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels
• Top soil: fit for use based on generic levels for residential areas

Examples of sensitive uses that may require site-specific remediation goals:
• Use of soil as kitchen garden
• Use of soil as playground, potential exposure of children to lead

Most likely remediation measures

Source
• Excavation of soil to a concentration level meeting the remediation objective
• Covering by pavement or layer of clean soil

Pathway (plume): n.a.

Receptor:
• Imposed limits to site use (e.g. no unauthorized digging)

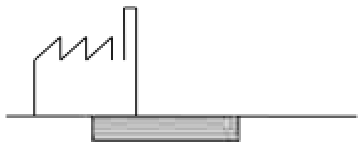
Specific conditions or alternative approaches

• Excavation is more efficient as part of a redevelopment project that involves excavating anyway
• While redeveloping, soil surface elevation can be considered to avoid large volumes of excavated soil
• An alternative option to reduce contact risk may be chemical immobilisation or physical immobilisation (grouting)
• In-situ strategies towards hexavalent chromium are mostly based on reduction to the less toxic and less mobile trivalent chromium by chemical or microbiological means. These techniques are mostly in a laboratory or pilot phase of development

Option 8: Remediation of land bound solid phase contamination in industrial areas

Site and setting summary

Type S1 : Land bound solid phase contamination
Setting: Industrial area
Risks: Direct human contact
Most common contaminant: heavy metals, PAH



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels
• Top soil: fit for use based on generic levels for industrial areas

Examples of sensitive uses that may require site-specific remediation goals:
• Unpaved sites sensitive to spreading by dust

Most likely remediation measures

Source
• Excavation of soil to a concentration level meeting the remediation objective
• Capping with pavement
• Combined with redevelopment: isolation under new building

Pathway (plume): n.a.

Receptor:
• Imposed limits to site use (e.g. no unauthorized digging)

Specific conditions or alternative approaches

• Specific excavation of hotspots can be considered as alternative approach, but requires detailed site assessment
• An alternative option to reduce contact risk may be chemical immobilisation or physical immobilisation (grouting)
• In-situ strategies towards hexavalent chromium are mostly based on reduction to the less toxic and less mobile trivalent chromium by chemical or microbiological means . These techniques are mostly in a laboratory or pilot phase of development
• Treatment of the actual cause of the pollution (industrial activity), if still present, should be performed before starting remedial action

Option 9: Remediation of liquid phase contamination

Site and setting summary

Type L: Liquid phase contamination
Setting: all site uses
Risks: Direct human contact
Most common contaminant: industrial effluents

Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels
- Top soil: fit for use based on generic levels corresponding with site use
- Subsoil and groundwater: steady end state and removal of risks

Examples of sensitive uses that may require site-specific remediation goals
- Habitation (soil vapour intrusion)

Most likely remediation measures

Source
- Excavation (above groundwater)
- Soil vapour extraction

Pathway (plume):
- Pump & Treat (combined with excavation)
- Multi Phase Extraction (combined with excavation)
- Bioremediation (combined with excavation)
- ISCO (combined with excavation)

Receptor
- Forced ventilation of basement/crawl space, sealing of floors (soil vapour intrusion)
- Imposed limits to site use (e.g. no unauthorized digging)

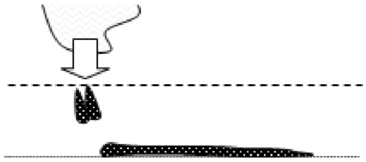
Specific conditions or alternative approaches

- Remediation of source and plume are often combined to obtain the most (cost) efficient remediation
- Several combinations of techniques for source and path remediation are possible, depending on site circumstances and project boundary conditions (timeframe, setting)
- Steady state is a situation, not a concentration level, therefore target concentration levels are not applicable. Proof of steady state is gathered by periodic sampling, condition for steady state is sufficient source load removal (e.g. 80% load removal)
- Typically, steady state does not require complete removal, but only removal of the mobile fraction of the contamination
- Inner air sampling is required to determine actual soil vapour risks; models will overestimate

Option 10: Dense Non-Aqueous Phase Liquid (DNAPL)

Site and setting summary

Type P1-a: Dense Non-Aqueous Phase Liquid in permeable soil (often found in combination with a P2 type)
Setting: Industrial site
Risks: inhalation (if no ground water present), spreading to groundwater
Most common contaminant: VOC, tar/heavy oil related contaminants, PCB



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- inhalation risk reduction (soil vapour)
- spreading risk reduction by:
    - mass removal as far as needed to reach a steady state plume
    - mass control (containment)

Most likely remediation measures

Exposure risk removal
- Soil vapour extraction and air sparging
- Vapour proof sealing in building floor

Spreading risk removal by mass removal
- Excavation
- Multi phase extraction
- Shock load bioremediation

Spreading risk reduction by mass control
- Physical/Hydraulic barriers
- Permeable reactive barriers

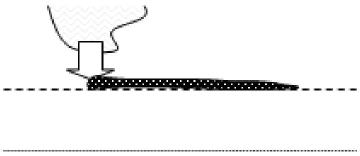
Specific conditions or alternative approaches

- DNAPL characterisation difficult due to irregular spreading pathways and specialized soil investigation techniques.
- Risk of unintentional DNAPL vertical transport by faulty monitoring wells or drillings.
- Specialized (and thus expensive) in-situ techniques may be worth considering if a high degree of source removal in needed a very short time frame. Example techniques are: chemical oxidation, surfactant-enhanced subsurface remediation, cosolvent flushing, steam/hot air injection and three/six-phase electrical resistance heating.
- Pump and treat is generally not recommended for DNAPL removal due to long lasting rebound of contaminations to groundwater.

Option 11: Light Non-Aqueous Phase Liquid (LNAPL)

Site and setting summary

Type P1-b: Light Non-Aqueous Phase Liquid (LNAPL) in permeable soil (often found in combination with a P2 type)
Setting: Industrial site
Risks: explosion, exposure, spreading to groundwater/surface water
Most common contaminant: VOC and light/medium fraction mineral oil



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Exposure/Explosion risk reduction
- Spreading risk reduction:
    - Mass removal as far as technique is cost effective. If
    - Mass control (containment)

Most likely remediation measures

In case of acute risks requiring immediate action
- Excavation
- Vapour proof sealing in building floor

In absence of acute risks
- Mass recovery: excavation, skimming, dual pump extraction
- Mass recovery by phase change: soil vapour extraction, air sparging, bio slurping
- Mass control: subsurface barrier, trench, wells

In case of low risk profile
- Long-term stewardship
- Natural source zone depletion

Specific conditions or alternative approaches

- The assessment of LNAPL spreading potential and the fitting remediation objectives requires specialist soil characterisation expertise.
- If chosen the right technique, the implementation of this technique to a point it is effective will typically lead to an acceptable risk reduction.
- Specialized (and thus expensive) in-situ techniques may be worth considering if a high degree of source removal in needed a very short time frame. Example techniques are: in-situ chemical oxidation, surfactant-enhanced subsurface remediation, co solvent flushing, steam/hot air injection, radio-frequency heating and three/six-phase electrical resistance heating.
- Pump and treat is generally not recommended for LNAPL removal due to long lasting rebound of contaminations to groundwater.

Option 12: Remediation of cluster of land bound solid phase contamination

Site and setting summary

Type S1-a/b: Cluster of land bound solid phase contamination
Setting: Multiple sites and site usages
Risks: Direct human contact, ecological risks (depending on site use)
Most common contaminant: heavy metals, PAH, pesticides

Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Top soil: fit for use based on generic level corresponding with site use
- Gradual improvement of soil quality over time towards a acceptable risk level and a minimal of site use restrictions

Most likely remediation measures

Technical aspects of the remediation can be found in the description of options for the non-clustered sites of the same type. The cluster approach differs from this sitewise approach regarding the management and coordination of the remediation of all the sites in the cluster area. Examples of aspects in dealing with cluster sites are:
- Remediation strategy and target levels established for the whole area
- Logistical solution for subsequent remediation of individual sites, such as a single sanitary landfill or central mobile soil treatment plant
- A single tender procedure
- A single generic remediation plan to be fine-tuned for individual sites, taking into account site specific conditions and site use
- A single organization dealing with post-remediation procedures
- A single generic plan for soil management (use, reuse and interchange between individual contaminated sites)

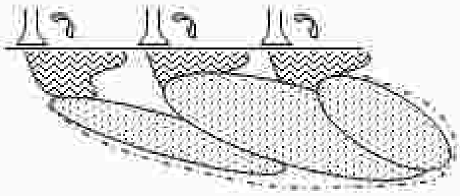
Specific conditions or alternative approaches

- Awareness of local aberrations in contamination situation required
- Generic remediation plans need updating every couple of years to remain aligned with developments in policy, state of the art in remediation approaches and changes in site use

Option 13: Remediation of cluster of liquid phase contamination

Site and setting summary:

Type L1: Cluster of liquid phase contamination
Setting: multiple sites and site usages, urban area
Risks: Direct human contact, exposure to polluted drinking water, spreading
Most common contaminant: mobile organic compounds



Draft sketch of typical field situation

Most likely remediation objectives

Recommendations for cleanup standards and levels:
- Top soil: site-specific levels for risk removal or risk reduction
- Subsoil and groundwater: steady end state and removal or reduction of risks over entire system area to be reached over longer timeframe (typically 30 to 40 years)
- Target levels for load removal for individual plumes, based on their contribution to the total plume volume and spreading
- Custom signal and action levels to evaluate spreading (towards receptors).

Most likely remediation measures

Principle: area oriented approach of groundwater remediation

Technical aspects:
- The approaches as listed under the description of the option for P2
- MNA – monitored natural attenuation
- Stimulation of biodegradation of the contaminants
- Monitoring of the groundwater quality to protect receptors

Strategic instruments:
- Remediation strategy and warning or action levels to be developed for the entire area
- Generic remediation plan for the entire area and underlying site specific remediation plans to assess hot spots (leaching) and establish load removal
- A single organization dealing with post-remediation procedures

Specific conditions or alternative approaches

- The area oriented approach is only used in cases where assessment of individual plumes is not technically feasible because remedial action applied to one plume will affect other plumes
- Active, immediate remediation (topsoil, source, plume, receptor) is only applied in case of actual risks
- Signal level: level of contamination at which additional attention is required, e.g. more intense sampling over time or space
- Action level: level of contamination at which additional active measures are required
- Low intensity remediation techniques (vertical biological or chemical barrier) can be considered if active prevention of spreading out of the area towards receptors is required

Volume III

5.5-i Examples of methods for remediation option evaluation

Volume III-5.5-i
Examples of methods for remediation option evaluation

1 Introduction

This Section presents examples of different methods for remediation option evaluation which is most relevant for Step 5.5 Selection remediation option. Following methods will be explained:
- descriptive methods;
- qualitative overview methods;
- quantitative overview methods.

2 Descriptive methods

Descriptive methods lead to a 'text only' description of the criteria. These methods are favoured in relatively simple situations, with few and simple remediation options. The results will provide a basis for remediation option appraisal. Descriptive methods are straightforward without any restrictive rules, but the results typically do not present a clear overview of the differences among the remediation options. A set of criteria is presented in the *Checklist Criteria for comparison and approval of remediation options, Volume II-5.5-a.* This checklist includes following criteria:
- Generic criteria: Risk reduction potential, Technical success potential, Cost and benefits, Sustainability;
- Site specific criteria: Time, Post remediation site use, Social criteria.

3 Qualitative overview method

In qualitative overview methods, the remediation options are subjected to qualitative judgment with respect to costs, burdens and benefits. These methods are favoured in relatively complex situations, with a wide variety of remediation options. Aspects that are comparatively similar in the different remediation options are eliminated, resulting in a clear identification of the criteria that really make the difference. The eventual selection of the most applicable remediation option can then be based on just these critical aspects. The results of these methods are typically presented in a table showing the pros and cons of the remediation options

An advantage of qualitative overview methods is that the results will present a clear overview of the most characteristic differences among the remediation options. Furthermore, they support constructive stakeholder involvement. On the other hand, these methods require a certain effort to perform, and the results may not provide enough information to finalise the selection of the most applicable remediation option.

Figure III-5.5-i-1 shows an example of a table presenting the results of a Costs Benefits Analysis. The results of such analysis are presented in a table showing burdens and benefits for each appraised remediation option. This particular example is based on the ROSA guideline (Guideline for decision making when dealing with mobile soil contaminants), used in The Netherlands.

Figure III-5.5-i-1 Example of a table presenting results of Costs Benefits Analysis

Criteria	Option 1	Option 2	Option 3
Burden			
Costs	1.000.000	500.000	350.000
Duration of remediation and post remediation	4 years, no post remediation (short)	2 years	
Failure risk	Average to high	Average	Average
Effects on other environment and surroundings	Large	Small	Small
Benefits			
Risk reduction	<MTR	<MTR	<MTR
Site recovery potential	Complete	Limited	None
Groundwater plume behaviour	Decreasing within 4 years	Decreasing within 15 years	Decreasing within 30 years
Removed contamination load	90%	80-90%	60-80%
Liability reduction	Large	Average	Small

While not guaranteeing an easy decision, this table does present a transparent overview of critical criteria, clearly showing the differences among the remediation options. This renders it a useful tool towards the eventual selection of the most applicable remediation option.

4 Quantitative overview method

The quantitative method is a Multi Criteria Analysis (MCA), based on the ranking of a series of criteria for each remediation option. Users may change criteria and arrange categories depending on individual approaches. Each criterion is assessed with a score ranging from 1 to 9 (where 9 stands for the highest impact). Each criterion can be weighted with a factor, reflecting the importance of the criterion compared to others. The scores are then added into subtotal scores and a total score. The highest scoring remediation option theoretically is the most applicable.

Results are typically presented in a weighting table. Bar or line charts may help to get a clear overview of the results.

Figure III-5.5-i.2 shows an example of a Multiple Criteria Analysis (MCA) weighting table, which illustrates the concept of MCA. This particular example is based on the Surf-UK/Surf-US programmes.
Figure III-5.5-i.3 shows an example visualisations of a MCA weighting table.

An advantage of quantitative overview methods is that it facilitates the selection by clearly showing one or two preferential options. However, while the translation of remediation option characteristics into a score is easy to do, it can also lead to a pseudo accuracy not always in accordance with reality. The use of mathematical decision techniques like Multi Criteria Analysis (MCA) may strengthen this effect. To prevent irrational decision making one should always keep an eye on reality while using these methods.

Figure III-5.5-i.2 Example of a MCA weighting table

Aspects (categories)	Weighting-factor	Options 1	2	…
Environmental				
Impacts on air (including climate change)	3	2	5	…
Impacts on soil	2	5	1	…
Impacts on water	2	3	1	…
Impacts on ecology	1	4	3	…
Use of natural resources and generation of wastes	3	1	2	…
Intrusiveness	1	2	4	…
Weighted group subtotal	***12***	***31***	***32***	…
Economic				
Direct economic costs and benefits	1	5	5	…
Indirect economic costs and benefits	1	4	2	…
Employment and capital gain	2	2	4	…
Gearing	2	4	1	…
Life-span and 'project risks'	1	1	3	…
Project flexibility	3	3	3	…
Weighted group subtotal	***10***	***37***	***40***	…
Social				
Impacts on human health and safety	3	2	4	…
Ethical and equity considerations	2	2	4	…
Impacts on neighbourhoods or regions	1	5	3	…
Community involvement and satisfaction	1	5	2	…
Compliance with policy objectives and strategies	2	4	5	…
Uncertainty and evidence	1	3	1	…
Weighted group subtotal	***10***	***40***	***44***	…
Total	**32**	**108**	**116**	**…**

Options. Number of options is typically 3 to 6, depending on the complexity of the remediation.

Weighting factors: important criteria are assigned more weight.

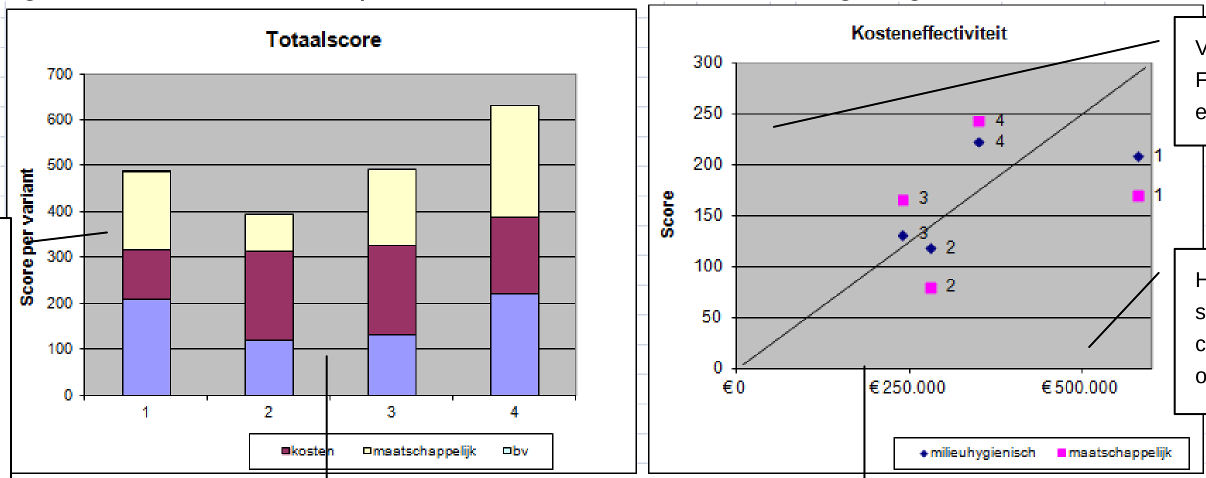
Description of aspects to be ranked.

Score of each criterion in each alternative.

Subtotals enable to see which alternative has a better consideration of each individual category.

Totals of each option. The highest score theoretically is the most applicable option.

Figure III-5.5-i.3   Example of visualisations of a MCA weighting table



Vertical scale: Final score of each option.

Option wise bar charts, showing the score of each individual category of criteria.

Horizontal scale: Total costs of each option.

In this kind of chart, the total score is dissected into the scores of each category of criteria on which the remediation options are ranked. This representation is useful to gain a quick, albeit synthesized, insight on the applicability of each remediation option.

This kind of chart answers the question: is the remediation option better, even if the cost is the highest?

5 Sustainable Costs-Benefits Analysis

Principle

A Sustainable Costs-Benefits Analysis Another can be made using a formula[1] allowing to see the balance between the costs and benefits and to see whether the benefits of the preferred remediation option exceed the costs associated with implementing the remedial option. This method implies to monetize costs and benefits for each of the used categories.

$$SR = \sum \left(\left(Benefit - Cost \right) + \left(Benefit - Cost \right) + \left(Benefit - Cost \right) \right)$$

- SR is the 'sustainable remediation score' for each of the n remedial options that can achieve the agreed remedial objectives;
- Benefit x is the benefit associated with each factor (environment, society or economy) for each remedial option; and
- Cost x is the cost associated with each factor (environment, society or economy) for each remedial option.

The optimum remedial option achieves:

- SR ≥ 0;
- SR is the maximum for the feasible remedial options 1 to n; and
- A fair distribution of the costs and benefits amongst the affected parties

Pros and Cons

This method gives easily one or two preferential options and facilitates the decision making.

However, the translation of option characteristics into a score might work easily in a technical way but gives a pseudo accuracy not always meeting reality. The use of mathematical decision techniques like Multi Criteria Analyses (MCA) might even strengthen this effect.

[1] A Framework for Assessing the Sustainability of Soil and Groundwater Remediation, www.claire.co.uk/index.php?option=com_content&view=article&id=182&Itemid=78&limitstart=7, CL:AIRE.

Volume III

6-i Manual for environmental and social impact assessment for remediation of contaminated sites

Volume III-6-i
Manual for Environmental and Social Impact Assessment for remediation of contaminated sites

1 Introduction

This section provides the aspects relevant for development of an Environmental and Social Impact Assessment for remediation of contaminated sites. The Environmental Impact Assessment is an existing regulatory instrument since 1994 especially used in case of industrial manufacturing activity and building construction projects. The remediation of contaminated sites can be added to the scope of this instrument with following remarks. An Environmental Impact Assessment is aimed to evaluate the possible negative effects of the intended activities which includes almost always a permanent change of the situation. The remediation of a contaminated site has different characteristics. First of all the intention for remediation is to eliminate or at least reduce the risks caused by existing contaminated material. The activities in this way are especially meant to have a positive environmental impact. Secondly the remediation activities often are temporary activities.

Nevertheless it has to be stated that remediation activities itself can have negative impact on the environment e.g. noise, dust, use of energy and water. Because of that it is required to carry out an Environmental Impact Assessment.

Section 2 provides the elements relevant for Environmental Impact Assessment.
In section 2.1 the below tables (I), (II) and (III) provide a checklist helpful for reporting. In table (II) some of the elements that are not preliminary related to remediation of contaminated sites have been marked with ‘N’ in the column Yes/No. Section 2.2 provides more descriptive information regarding the important elements for and EIA.

Section 3 provides the aspects relevant for Social Impact Assessment.

For more detail information on Environmental Impact Assessment reference is made to EIA notification S.O.1533(E) dated 14 09 2006, Sr. No. 16 under:
http://envfor.nic.in/environmental_clearancegeneral
And for EIA specific manuals we refer to:
http://envfor.nic.in/essential-links/eia-specific-manuals

2 Elements of Environmental Impact Assessment

2.1 Tables

(I) Basic Information	
Name of the Project:	
Location / site alternatives under consideration:	
Size of the Project:	
Expected cost of the project:	
Contact Information:	
Screening Category:	

(II) Activity

1. Construction, operation or decommissioning of the Project involving actions, which will cause physical changes in the locality (topography, land use, changes in water bodies, etc.)

S.No.	Information/Checklist confirmation	Yes/No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
1.1	Permanent or temporary change in land use, land cover or topography including increase in intensity of land use (with respect to local land use plan)		
1.2	Clearance of existing land, vegetation and buildings?		
1.3	Creation of new land uses?		
1.4	Pre-construction investigations e.g. bore houses, soil testing?		
1.5	Construction works?		
1.6	Demolition works?		
1.7	Temporary sites used for construction works or housing of construction workers?		
1.8	Above ground buildings, structures or earthworks including linear structures, cut and fill or excavations		
1.9	Underground works including mining or tunnelling?		
1.10	Reclamation works?		
1.11	Dredging?		
1.12	Offshore structures?	N	
1.13	Production and manufacturing processes?	N	
1.14	Facilities for storage of goods or materials?		
1.15	Facilities for treatment or disposal of solid waste or liquid effluents?		
1.16	Facilities for long term housing of operational workers?		
1.17	New road, rail or sea traffic during construction or operation?		
1.18	New road, rail, air waterborne or other transport infrastructure including new or altered routes and stations, ports, airports etc.?	N	
1.19	Closure or diversion of existing transport routes or infrastructure leading to changes in traffic movements?	N	
1.20	New or diverted transmission lines or pipelines?	N	
1.21	Impoundment, damming, culverting, realignment or other changes to the hydrology of watercourses or aquifers?		
1.22	Stream crossings?	N	

1.23	Abstraction or transfers of water from ground or surface waters?		
1.24	Changes in water bodies or the land surface affecting drainage or run-off?		
1.25	Transport of personnel or materials for construction, operation or decommissioning?		
1.26	Long-term dismantling or decommissioning or restoration works?		
1.27	Ongoing activity during decommissioning which could have an impact on the environment?		
1.28	Influx of people to an area in either temporarily or permanently?		
1.29	Introduction of alien species?	N	
1.30	Loss of native species or genetic diversity?	N	
1.31	Any other actions?		

Explanation: N means this that from the possible activities during a remediation this activity will surely not apply to a contaminated site remediation project.

2. Use of Natural resources for construction or operation of the Project (such as land, water, materials or energy, especially any resources which are non-renewable or in short supply):

S.No.	Information/Checklist confirmation	Yes/No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
2.1	Land especially undeveloped or agricultural land (ha)		
2.2	Water (expected source & competing users) unit: KLD		
2.3	Minerals (MT)	N	
2.4	Construction material – stone, aggregates, sand / soil (expected source – MT)		
2.5	Forests and timber (source – MT)	N	
2.6	Energy including electricity and fuels (source, competing users) Unit: fuel (MT), energy (MW)		
2.7	Any other natural resources (use appropriate standard units)		

3. Use, storage, transport, handling or production of substances or materials, which could be harmful to human health or the environment or raise concerns about actual or perceived risks to human health.

S.No.	Information/Checklist confirmation	Yes/No	Details thereof (with approximate quantities /rates, wherever possible) with source of information data
3.1	Use of substances or materials, which are hazardous (as per MSIHC rules) to human health or the environment (flora, fauna, and water supplies)		
3.2	Changes in occurrence of disease or affect disease vectors (e.g. insect or water borne diseases)	N	
3.3	Affect the welfare of people e.g. by changing living conditions?		
3.4	Vulnerable groups of people who could be affected by the project e.g. hospital patients, children, the elderly etc.,		
3.5	Any other causes		

4. Production of solid wastes during construction or operation or decommissioning (MT/month).			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
4.1	Spoil, overburden or mine wastes	N	
4.2	Municipal waste (domestic and or commercial wastes)		
4.3	Hazardous wastes (as per Hazardous Waste Management Rules)		
4.4	Other industrial process wastes	N	
4.5	Surplus product		
4.6	Sewage sludge or other sludge from effluent treatment		
4.7	Construction or demolition wastes		
4.8	Redundant machinery or equipment	N	
4.9	Contaminated soils or other materials		
4.10	Agricultural wastes	N	
4.11	Other solid wastes		

5. Release of pollutants or any hazardous, toxic or noxious substances to air (Kg/hr).			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
5.1	Emissions from combustion of fossil fuels from stationary or mobile sources		
5.2	Emissions from production processes	N	
5.3	Emissions from materials handling including storage or transport		
5.4	Emissions from construction activities including plant and equipment		
5.5	Dust or odours from handling of materials including construction materials, sewage and waste		
5.6	Emissions from incineration of waste		
5.7	Emissions from burning of waste in open air (e.g. slash materials, construction debris)		
5.8	Emissions from any other sources		

6. Generation of Noise and Vibration, and Emissions of Light and Heat.			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
6.1	From operation of equipment e.g. engines, ventilation plant, crushers		
6.2	From industrial or similar processes		
6.3	From construction or demolition		
6.4	From blasting or piling		
6.5	From construction or operational traffic		
6.6	From lighting or cooling systems		
6.7	From any other sources		

7. Risks of contamination of land or water from releases of pollutants into the ground or into sewers, surface waters, groundwater, coastal waters or the sea.			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
7.1	From handling, storage, use or spillage of hazardous materials		
7.2	From discharge of sewage or other effluents to water or the land (expected mode and place of discharge)		
7.3	By deposition of pollutants emitted to air into the land or into water		
7.4	From any other sources		
7.5	Is there a risk of long term build up of pollutants in the environment from these sources?		

8. Risk of accidents during construction or operation of the Project, which could affect human health or the environment.			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
8.1	From explosions, spillages, fires etc. from storage, handling, use or production of hazardous substances	N	
8.2	From any other causes		
8.3	Could the project be affected by natural disasters causing environmental damage (e.g. floods, earthquakes, landslides, cloudburst etc.)?		

9. Factors which should be considered (such as consequential development) which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality.			
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
9.1	Lead to development of supporting facilities, ancillary development or development stimulated by the project which could have impact on the environment e.g.: • Supporting infrastructure (roads, power supply, waste or waste water treatment, etc.) • housing development • extractive industries • supply industries • other	N	
9.2	Lead to after-use of the site, which could have an impact on the environment	N	
9.3	Set a precedent for later developments		
9.4	Have cumulative effects due to proximity to other existing or planned projects with similar effects	N	

(III)	Environmental Sensitivity		
S.No.	**Information/Checklist confirmation**	**Yes/No**	**Details thereof (with approximate quantities /rates, wherever possible) with source of information data**
1	Areas protected under international conventions, national or local legislation for their ecological, landscape, cultural or other related value		
2	Areas which are important or sensitive for ecological reasons - Wetlands, watercourses or other water bodies, coastal zone, biospheres, mountains, forests		
3	Areas used by protected, important or sensitive species of flora or fauna for breeding, nesting, foraging, resting, over wintering, migration		
4	Inland, coastal, marine or underground waters		
5	State, National boundaries		
6	Routes or facilities used by the public for access to recreation or other tourist, pilgrim areas		
7	Defence installations		
8	Densely populated or built-up area		
9	Areas occupied by sensitive man-made land uses *(hospitals, schools, places of worship, community facilities)*		
10	Areas containing important, high quality or scarce resources *(ground water resources, surface resources, forestry, agriculture, fisheries, tourism, minerals)*		
11	Areas already subjected to pollution or environmental damage. *(those where existing legal environmental standards are exceeded)*		
12	Areas susceptible to natural hazard which could cause the project to present environmental problems (*earthquakes, subsidence, landslides, erosion, flooding or extreme or adverse climatic conditions*)		

2.2 Additional information

For Construction projects there is a separate checklist of environmental impacts. This checklist provides more descriptive information and are in this way additional to the elements mentioned in the above tables (I), (II) and (III).

CHECKLIST OF ENVIRONMENTAL IMPACTS for Construction Project
(Project proponents are required to provide full information and wherever necessary attach explanatory notes with the Form and submit along with proposed environmental management plan & monitoring programme)

1. LAND ENVIRONMENT

1.1. Will the existing landuse get significantly altered from the project that is not consistent with the surroundings? (Proposed landuse must conform to the approved Master Plan / Development Plan of the area. Change of landuse if any and the statutory approval from the competent authority be submitted). Attach Maps of (i) site location, (ii) surrounding features of the proposed site (within 500 meters) and (iii)the site (indicating levels & contours) to appropriate scales. If not available attach only conceptual plans.

1.2. List out all the major project requirements in terms of the land area, built up area, water consumption, power requirement, connectivity, community facilities, parking needs etc.

1.3. What are the likely impacts of the proposed activity on the existing facilities adjacent to the proposed site? (Such as open spaces, community facilities, details of the existing landuse, disturbance to the local ecology).

1.4. Will there be any significant land disturbance resulting in erosion, subsidence & instability? (Details of soil type, slope analysis, vulnerability to subsidence, seismicity etc. may be given).

1.5. Will the proposal involve alteration of natural drainage systems? (Give details on a contour map showing the natural drainage near the proposed project site)

1.6. What are the quantities of earthwork involved in the construction activity-cutting, filling, reclamation etc. (Give details of the quantities of earthwork involved, transport of fill materials from outside the site etc.)

1.7. Give details regarding water supply, waste handling etc. during the construction period.

1.8. Will the low lying areas & wetlands get altered? (Provide details of how low lying and wetlands are getting modified from the proposed activity)

1.9. Whether construction debris & waste during construction cause health hazard? (Give quantities of various types of wastes generated during construction including the construction labor and the means of disposal)

2. WATER ENVIRONMENT

2.1. Give the total quantity of water requirement for the proposed project with the breakup of requirements for various uses. How will the water requirement met? State the sources & quantities and furnish a water balance statement.

2.2. What is the capacity (dependable flow or yield) of the proposed source of water?

2.3. What is the quality of water required, in case, the supply is not from a municipal source? (Provide physical, chemical, biological characteristics with class of water quality)

2.4. How much of the water requirement can be met from the recycling of treated wastewater? (Give the details of quantities, sources and usage)

2.5. Will there be diversion of water from other users? (Please assess the impacts of the project on other existing uses and quantities of consumption)

2.6. What is the incremental pollution load from wastewater generated from the proposed activity? (Give details of the quantities and composition of wastewater generated from the proposed activity)

2.7. Give details of the water requirements met from water harvesting? Furnish details of the facilities created.

2.8. What would be the impact of the land use changes occurring due to the proposed project on the runoff characteristics (quantitative as well as qualitative) of the area in the post construction phase on a long term basis? Would it aggravate the problems of flooding or water logging in any way?

2.9. What are the impacts of the proposal on the ground water? (Will there be tapping of ground water; give the details of ground water table, recharging capacity, and approvals obtained from competent authority, if any)

2.10. What precautions/measures are taken to prevent the run-off from construction activities polluting land & aquifers? (Give details of quantities and the measures taken to avoid the adverse impacts)

2.11. How is the storm water from within the site managed?(State the provisions made to avoid flooding of the area, details of the drainage facilities provided along with a site layout indication contour levels)

2.12. Will the deployment of construction labourers particularly in the peak period lead to unsanitary conditions around the project site (Justify with proper explanation)

2.13. What on-site facilities are provided for the collection, treatment & safe disposal of sewage? (Give details of the quantities of wastewater generation, treatment capacities with technology & facilities for recycling and disposal)

2.14. Give details of dual plumbing system if treated waste used is used for flushing of toilets or any other use.

3. VEGETATION

3.1. Is there any threat of the project to the biodiversity? (Give a description of the local ecosystem with it's unique features, if any)

3.2. Will the construction involve extensive clearing or modification of vegetation? (Provide a detailed account of the trees & vegetation affected by the project)

3.3. What are the measures proposed to be taken to minimize the likely impacts on important site features (Give details of proposal for tree plantation, landscaping, creation of water bodies etc. along with a layout plan to an appropriate scale)

4. FAUNA

4.1. Is there likely to be any displacement of fauna- both terrestrial and aquatic or creation of barriers for their movement? Provide the details.

4.2. Any direct or indirect impacts on the avifauna of the area? Provide details.

4.3. Prescribe measures such as corridors, fish ladders etc. to mitigate adverse impacts on fauna

5. AIR ENVIRONMENT

5.1. Will the project increase atmospheric concentration of gases & result in heat islands? (Give details of background air quality levels with predicted values based on dispersion models taking into account the increased traffic generation as a result of the proposed constructions)

5.2. What are the impacts on generation of dust, smoke, odorous fumes or other hazardous gases? Give details in relation to all the meteorological parameters.

5.3. Will the proposal create shortage of parking space for vehicles? Furnish details of the present level of transport infrastructure and measures proposed for improvement including the traffic management at the entry & exit to the project site.

5.4. Provide details of the movement patterns with internal roads, bicycle tracks, pedestrian pathways, footpaths etc., with areas under each category.

5.5. Will there be significant increase in traffic noise & vibrations? Give details of the sources and the measures proposed for mitigation of the above.

5.6. What will be the impact of DG sets & other equipment on noise levels & vibration in & ambient air quality around the project site? Provide details.

6. AESTHETICS

6.1. Will the proposed constructions in any way result in the obstruction of a view, scenic amenity or landscapes? Are these considerations taken into account by the proponents?

6.2. Will there be any adverse impacts from new constructions on the existing structures? What are the considerations taken into account?

6.3. Whether there are any local considerations of urban form & urban design influencing the design criteria? They may be explicitly spelt out.

6.4. Are there any anthropological or archaeological sites or artifacts nearby? State if any other significant features in the vicinity of the proposed site have been considered.

7. SOCIO-ECONOMIC ASPECTS

7.1. Will the proposal result in any changes to the demographic structure of local population? Provide the details.

7.2. Give details of the existing social infrastructure around the proposed project.

7.3. Will the project cause adverse effects on local communities, disturbance to sacred sites or other cultural values? What are the safeguards proposed?

8. BUILDING MATERIALS

8.1. May involve the use of building materials with high-embodied energy. Are the construction materials produced with energy efficient processes? (Give details of energy conservation measures in the selection of building materials and their energy efficiency)

8.2. Transport and handling of materials during construction may result in pollution, noise & public nuisance. What measures are taken to minimize the impacts?

8.3. Are recycled materials used in roads and structures? State the extent of savings achieved?

8.4. Give details of the methods of collection, segregation & disposal of the garbage generated during the operation phases of the project.

9. ENERGY CONSERVATION

9.1. Give details of the power requirements, source of supply, backup source etc. What is the energy consumption assumed per square foot of built-up area? How have you tried to minimize energy consumption?

9.2. What type of, and capacity of, power back-up to you plan to provide?

9.3. What are the characteristics of the glass you plan to use? Provide specifications of its characteristics related to both short wave and long wave radiation?

9.4. What passive solar architectural features are being used in the building? Illustrate the applications made in the proposed project.

9.5. Does the layout of streets & buildings maximise the potential for solar energy devices? Have you considered the use of street lighting, emergency lighting and solar hot water systems for use in the building complex? Substantiate with details.

9.6. Is shading effectively used to reduce cooling/heating loads? What principles have been used to maximize the shading of Walls on the East and the West and the Roof? How much energy saving has been effected?

9.7. Do the structures use energy-efficient space conditioning, lighting and mechanical systems? Provide technical details. Provide details of the transformers and motor efficiencies, lighting intensity and air-conditioning load assumptions? Are you using CFC and HCFC free chillers? Provide specifications.

9.8. What are the likely effects of the building activity in altering the micro-climates? Provide a self assessment on the likely impacts of the proposed construction on creation of heat island & inversion effects?

9.9. What are the thermal characteristics of the building envelope? (a) roof; (b) external walls; and (c) fenestration? Give details of the material used and the U-values or the R values of the individual components.

9.10. What precautions & safety measures are proposed against fire hazards? Furnish details of emergency plans.

9.11. If you are using glass as wall material provides details and specifications including emissivity and thermal characteristics.

9.12. What is the rate of air infiltration into the building? Provide details of how you are mitigating the effects of infiltration.

9.13. To what extent the non-conventional energy technologies are utilised in the overall energy consumption? Provide details of the renewable energy technologies used.

10. Environment Management Plan

The Environment Management Plan would consist of all mitigation measures for each item wise activity to be undertaken during the construction, operation and the entire life cycle to minimize adverse environmental impacts as a result of the activities of the project. It would also delineate the environmental monitoring plan for compliance of various environmental regulations. It will state the steps to be taken in case of emergency such as accidents at the site including fire.

3. Elements for Social Impact Assessment

The scope and depth of Social Impact Assessment (SIA) should be determined by the complexity and importance of issues studied, taking into account the skills and resources available. SIA should include studies related to involuntary resettlement, compulsory land acquisition, impact of imported workforces, job losses among local people, damage to sites of cultural, historic or scientific interest, impact on minority or vulnerable groups, child or bonded labor, use of armed security guards. However, SIA may primarily include the following:

Description of the socio-economic, cultural and institutional profile

Conduct a rapid review of available sources of information to describe the socioeconomic, cultural and institutional interface in which the project operates.

Socio-economic and cultural profile: Describe the most significant social, economic and cultural features that differentiate social groups in the project area. Describe their different interests in the project, and their levels of influence. Explain any specific effects, the project may have on the poor and underprivileged. Identify any known conflicts among groups that may affect project implementation.

Institutional profile: Describe the institutional environment; consider both the presence and function of public, private and civil society institutions relevant to the operation. Are there important constraints within existing institutions *e.g.* disconnect between institutional responsibilities and the interests and behaviors of personnel within those institutions? Or are there opportunities to utilize the potential of existing institutions, *e.g.* private or civil society institutions, to strengthen implementation capacity.

Legislative and regulatory considerations

To review laws and regulations governing the project's implementation and access of poor and excluded groups to goods, services and opportunities provided by the project. In addition, review the enabling environment for public participation and development planning. SIA should build on strong aspects of legal and regulatory systems to facilitate program implementation and identify weak aspects while recommending alternative arrangements.

Key social issues

SIA provides baseline information for designing social development strategy. The analysis should determine the key social and Institutional issues which affect the project objectives; identify the key stakeholder groups in this context and determine how relationships between stakeholder groups will affect or be affected by the project; and identify expected social development outcomes and actions proposed to achieve those outcomes.

Data collection and methodology

Describe the design and methodology for social analysis. In this regard:

- build on existing data;
- clarify the units of analysis for social assessment: intra-household, household level, as well as communities/settlements and other relevant social aggregations on which data is available or will be collected for analysis;

* choose appropriate data collection and analytical tools and methods, employing mixed methods wherever possible; mixed methods include a mix of quantitative and qualitative methods.

Strategy to achieve social development outcomes

Identify the likely social development outcomes of the project and propose a social development strategy, including recommendations for institutional arrangements to achieve them, based on the findings of the social assessment. The social development strategy could include measures that:

* strengthen social inclusion by ensuring inclusion of both poor and excluded groups and intended beneficiaries in the benefit stream; offer access to opportunities created by the project
* empower stakeholders through their participation in design and implementation of the project, their access to information, and their increased voice and accountability (*i.e*. a participation framework); and · that enhance security by minimizing and managing likely social risks and increasing the resilience of intended beneficiaries and affected persons to socio-economic shocks

Implications for analysis of alternatives

Review proposed approaches for the project, and compare them in terms of their relative impacts and social development outcomes. Consider what implications the findings of social assessment might have on those approaches. Should some new components be added to the approach, or other components be reconsidered or modified?

If SIA and consultation processes indicate that alternative approaches may to have better development outcomes, such alternatives should be described and considered, along with the likely budgetary and administrative effects these changes might have.

Recommendations for project design and implementation arrangements

Provide guidance to project management and other stakeholders on how to integrate social development issues into project design and implementation arrangements. As much as possible, suggest specific action plans or implementation mechanisms to address relevant social issues and potential impacts. These can be developed as integrated or separate action plans, for example, as Resettlement Action Plans, Indigenous Peoples Development Plans, Community Development Plans, *etc*.

Developing a monitoring plan

Through SIA process, a framework for monitoring and evaluation should be developed.

To the extent possible, this should be done in consultation with key stakeholders, especially beneficiaries and affected people.

The framework shall identify expected social development indicators, establish benchmarks, and design systems and mechanisms for measuring progress and results related to social development objectives. The framework shall identify organizational responsibilities in terms of monitoring, supervision, and evaluation procedures. Wherever possible, participatory monitoring mechanisms shall be incorporated. The framework should establish:

* a set of monitoring indicators to track the progress achieved. The benchmarks and indicators should be limited in number, and should combine both quantitative and qualitative types of data. The indicators should include outputs to be achieved by the social development strategy; indicators to monitor the process of stakeholder participation, implementation and institutional reform;
* indicators to monitor social risk and social development outcomes; and indicators to
* monitor impacts of the project's social development strategy. It is important to suggest mechanisms through which lessons learnt from monitoring and stakeholder feedback can result in changes to improve operation of the project. Indicators should be of such nature that results and impacts can be disaggregated by gender and other relevant social groups;
* Define transparent evaluation procedures. Depending on context, these may include a combination of methods, such as participant observation, key informant interviews, focus group discussions, census and socio-economic surveys, gender analysis, Participatory Rural Appraisal (PRA), Participatory Poverty Assessment (PPA) methodologies, and other tools. Such procedures should be tailored to the special conditions of the project and to the different groups living in the project area;

Estimate resource and budget requirements for monitoring and evaluation activities, and a description of other inputs (such as institutional strengthening and capacity building) needs to be carried out.