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, March 2015

Ministry of Environment and Forests
GOVERNMENT OF INDIA

Volume III
Introduction

Introduction to Volume III 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 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.

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 January 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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MINISTRY OF ENVIRONMENT AND FORESTS

INVENTORY AND MAPPING OF PROBABLY CONTAMI-NATED SITS IN INDIA

SITE INVESTIGATION PROTOCOL (SIP)

PROJECT NO. A019251
DOCUMENT NO. 6
VERSION 002
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PREPARED B. v. d. Enden, TJR
CHECKED TJR, MvV, SV
APPROVED TJR

CONTENTS

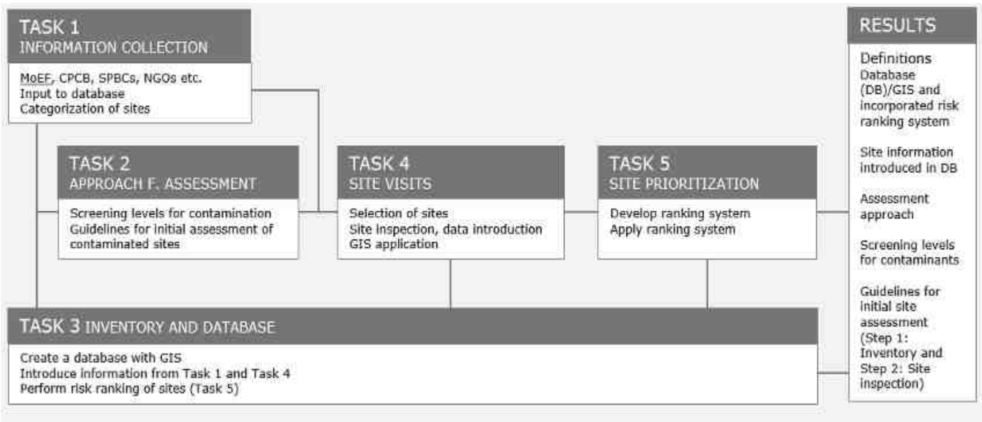
APPENDICES

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.

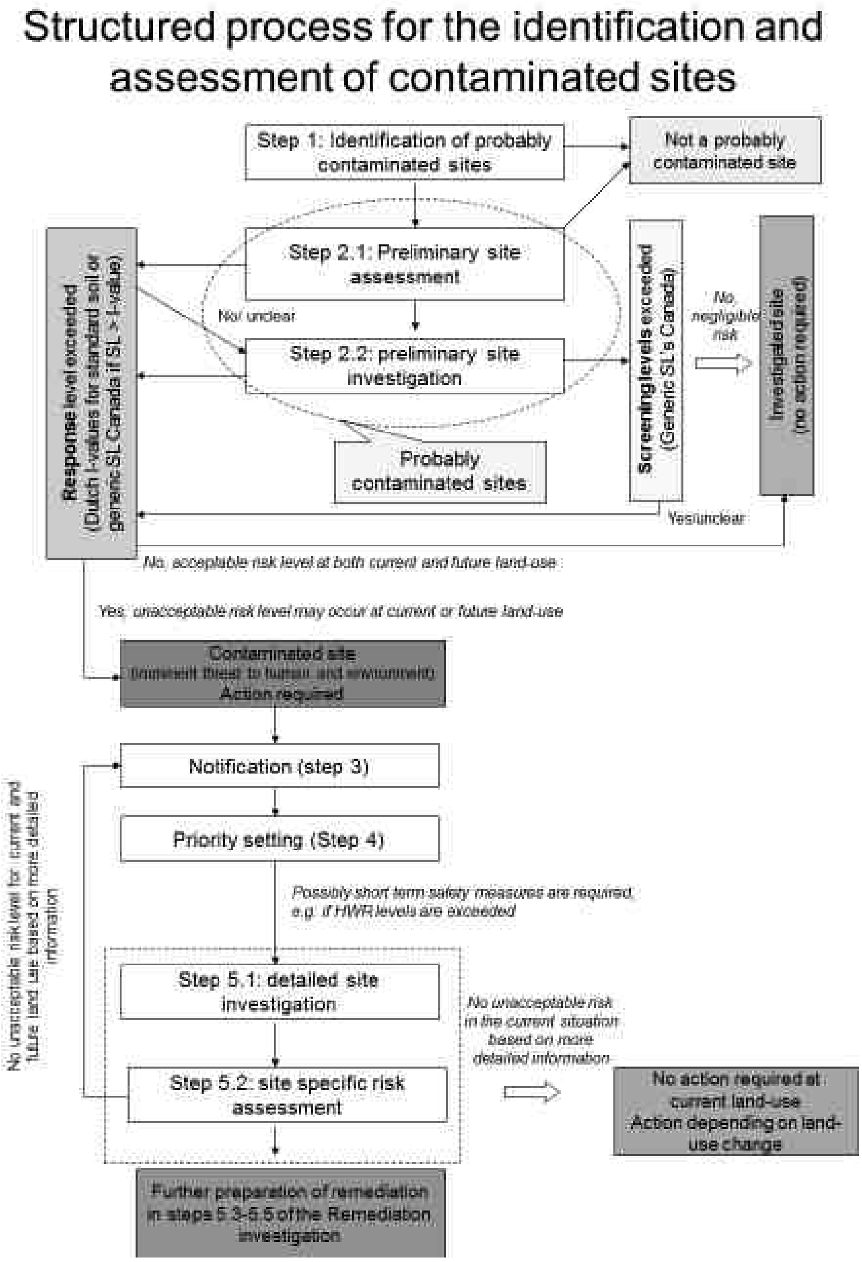
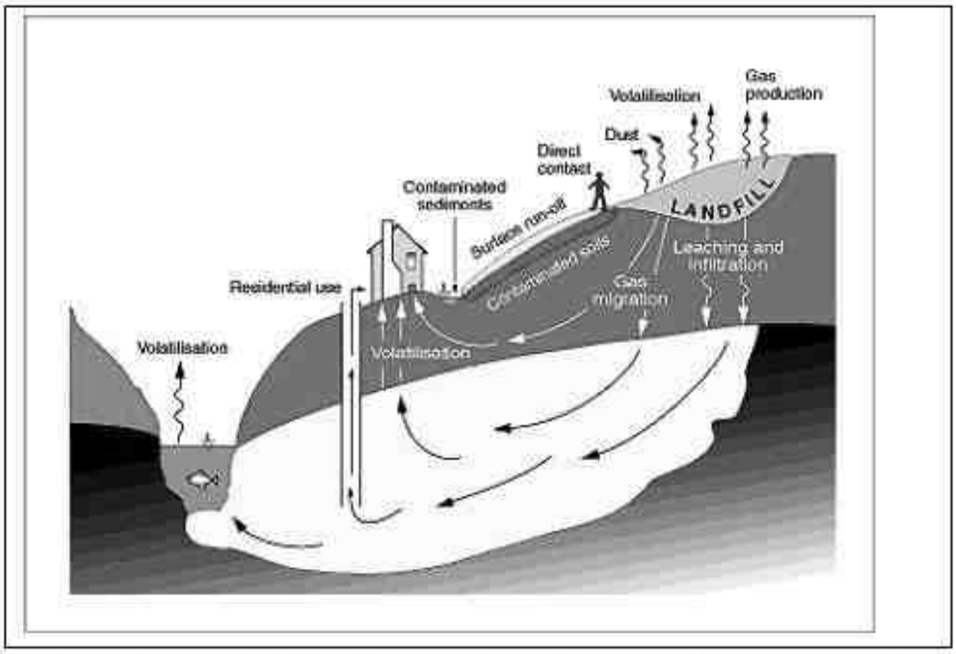


Figure 1-2 Structured process

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. Edulgee. 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 investigations performed an

Data sheet no. #		
		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 th 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 recreatio 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 tal 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 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. heavely 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 I: Methodologies and Guidance (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.

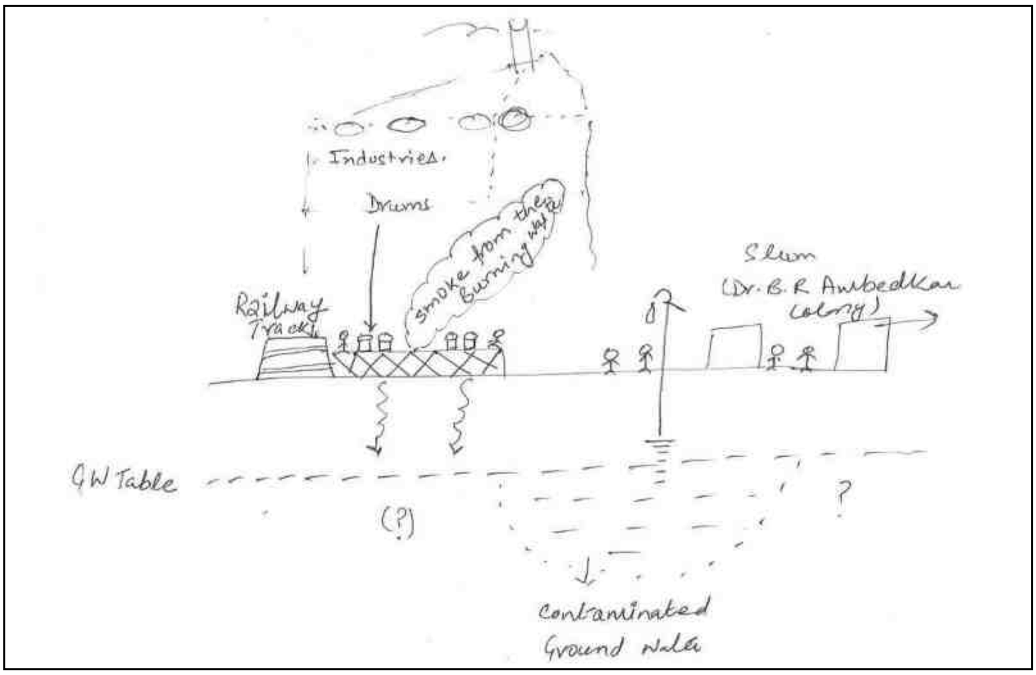
Based on the available information provide a sketch of the site's Conceptual Site Model:

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 the field staff in order to ensure quality of sampling, ensure uniformity and to allow for effective assessment of fieldwork quality.

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 (because 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.

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.
  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.

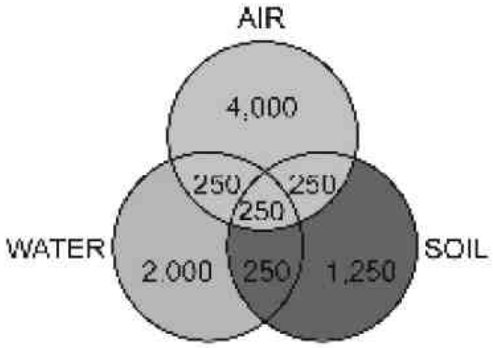
A worst case impacted population at risk estimate would include a larger number than the number of people who could be exposed to the toxic pollution. Examples might be:

› 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:



DO NOT DOUBLE COUNT POPULATIONS
Air: 4,750 (4,000 + 250 + 250 + 250)
Soil: 1,500 (1250 + 250)
Water: 2.000

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:

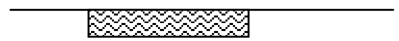
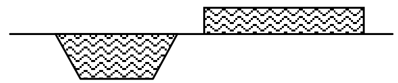
- **Type S1 and L** related subtypes are defined, based on the activity causing the contamination. HW-Schedule I (listing processes generating hazardous wastes) may help to focus on possible activities.
  In Table T1 these subtypes are coded ‘a’ through ‘f’ (type S) and ‘a’ through ‘d´ (type L).
  These subtypes are distinguished to support the site assessment.

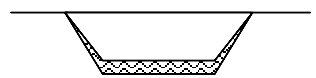
- **Type P1** related subtypes are defined, based on the bulk density of a NAPL (non aqueous phase liquids, dense and light).
  In Table T1 these subtypes are coded ‘a’ and ‘b’ (type P1).
  These subtypes are distinguished to support the site assessment.

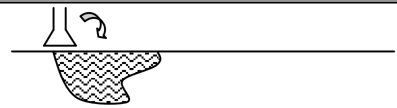
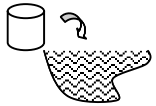
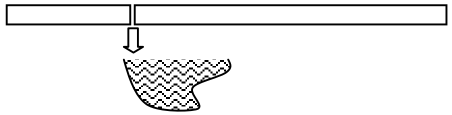
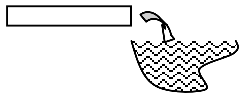
The typology is aimed to support the remediation options appraisal. Some examples to illustrate this point. A site assessment plan for a S1-f type contaminated site (deposition by flooding or washing) will focus on the boundaries of the flooded areas of a river system, easily recognizable on maps or 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.

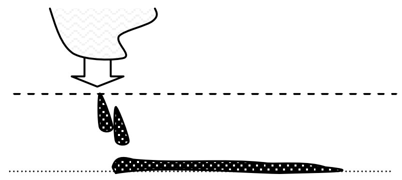
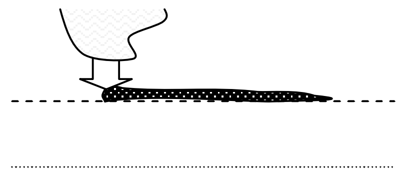
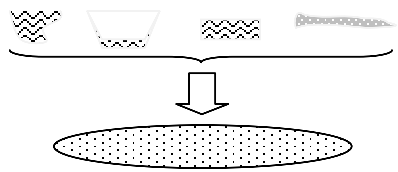
Table T1 Typology

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.

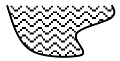
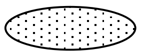
Type	Description or activity	Typical field characteristics of the site / examples	Icon with typical field situation (cross-section)
P-1	Liquid phase related		
P1-a	Dense Non-Aqueous Phase Liquid (DNAPL [a])) in permeable soil. (bulk density > water)	Spreading of liquids due to gravity flow resulting 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

MINISTRY OF ENVIRONMENT AND FORESTS

SITE INSPECTION FORM - TEMPLATE

SITE ID:
SITE NAME:
STATE:
STATUS:

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

CONTENTS

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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 ¤	Drinking water standards: Guidelines for Canadian Drinking Water Quality	Drinking water standards: 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	
	A**ssessment 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;

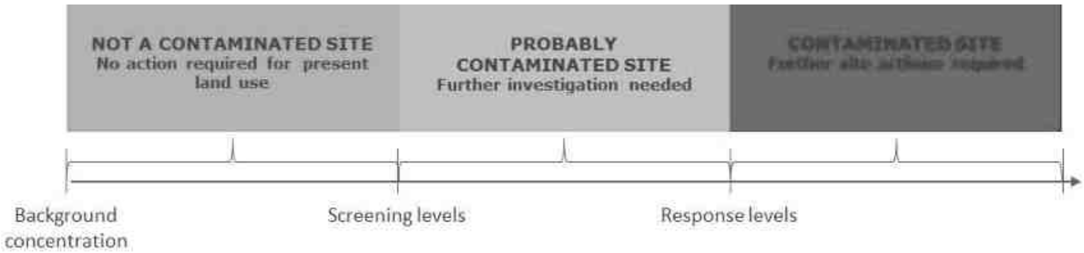
› Response Levels are generic concentrations of hazardous substances in soil and sediments, at or above which, it is very likely there is an imminent threat to human health or the environment. At or above this level some form of response is required to provide an adequate level of safety to protect public 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	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels)	**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	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
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	-	-	-	-		-		-	-	-	-		-

Chemical Name	Chemical Groups	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels)	**Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				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
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	-/-
Di-n-octyl phthalate	Phthalate esters	-		-	-	-	-	-	-		-	-	-	-	-	-/-
Dibenz(a,h)anthracene	Polycyclic aromatic hydrocarbons (PAH)	-		0.1 ¤	1 ¤	10 ¤	10 ¤	-	-		-	-	-	-	-	-/-

Chemical Name	Chemical Groups	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels	**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	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
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
Hexachlorocyclohexane (alfa HCH)	Pesticides, Organochlorine	-	17	-	-	-	-		-		-	-	-	-		
Hexachlorocyclohexane (beta HCH)	Pesticides, Organochlorine	-	1,6	-	-	-	-		-		-	-	-	-		

Chemical Name	Chemical Groups	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels)	**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	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
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	-
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	-	-

Chemical Name	Chemical Groups	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels)	**Screening leves** Soil Quality Guidelines for the Protection of Environmental and Human Health				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
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 compunds	-		-	-	-	-	200	-		-	-	-	-	-	No data
Sulphur (elemental)	Inorganic Inorganic sulphur compunds	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

Chemical Name	Chemical Groups	Soil (Screening and Response Levels)						Drinking water (Screening levels)			Surface water Quality (Screening levels)					
		Levels in soil (HW Rules, 2008)	**Response levels** (Dutch Intervention levels)	**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	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
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

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, 5 and 6.
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 occurence;
b. to help establish the extent to which contamination exceeds background levels and the area where this occurs.

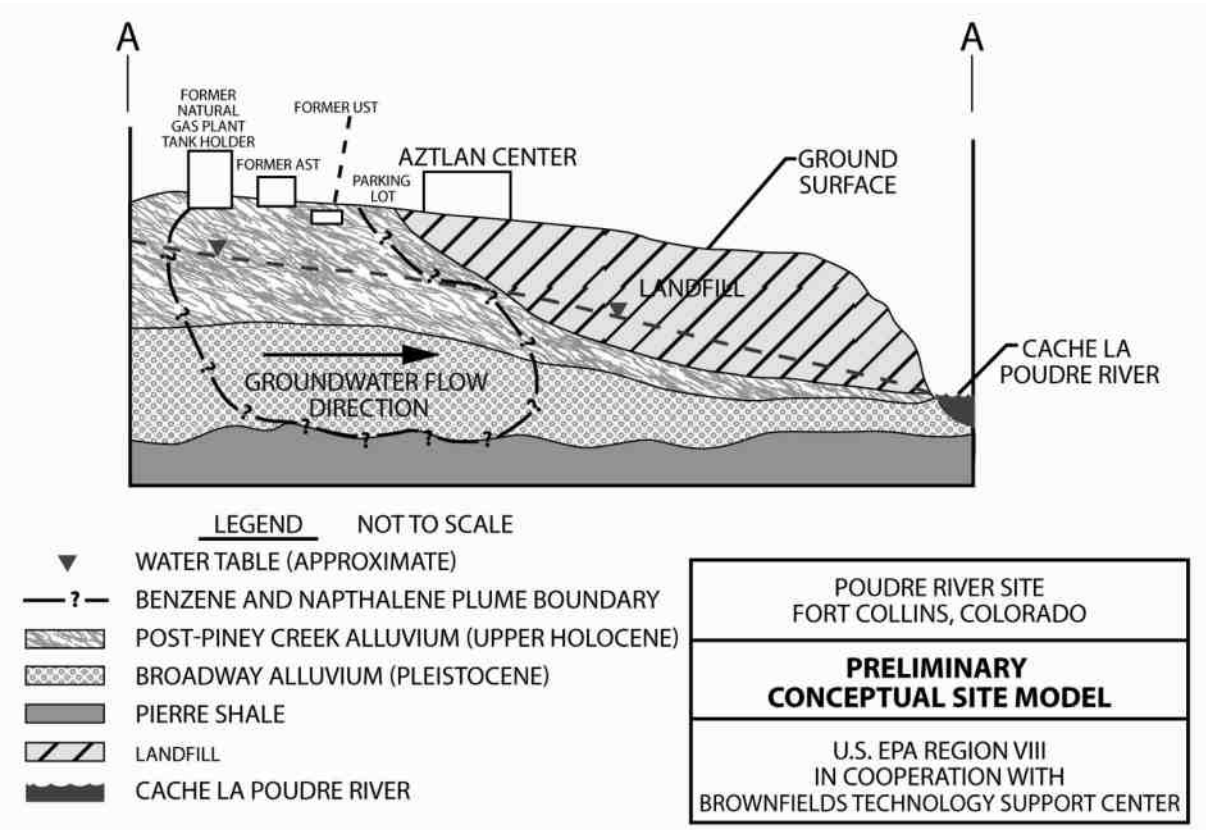
- Identifying and characterizing Source: the following source characteristics should be measured or estimated for a site, the level of detail depends on the position in the process of assessment and remediation. During detailed site assessment these elements should be considered more detailed compared 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 identified 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:

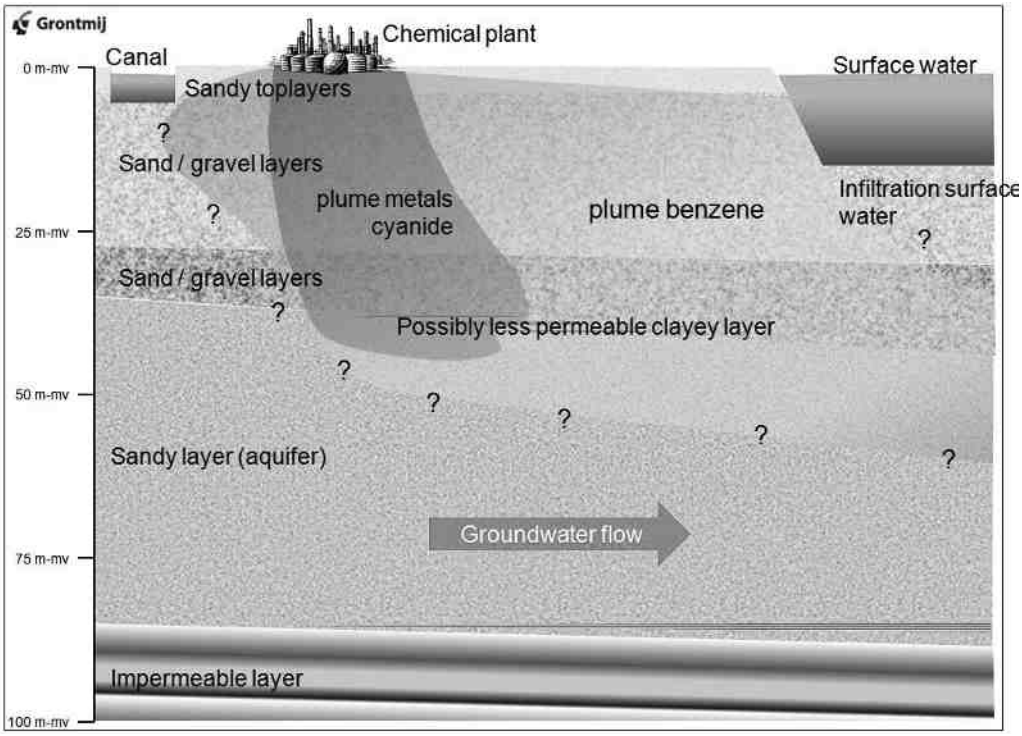
References to more detailed information on SPR and CSM

- 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

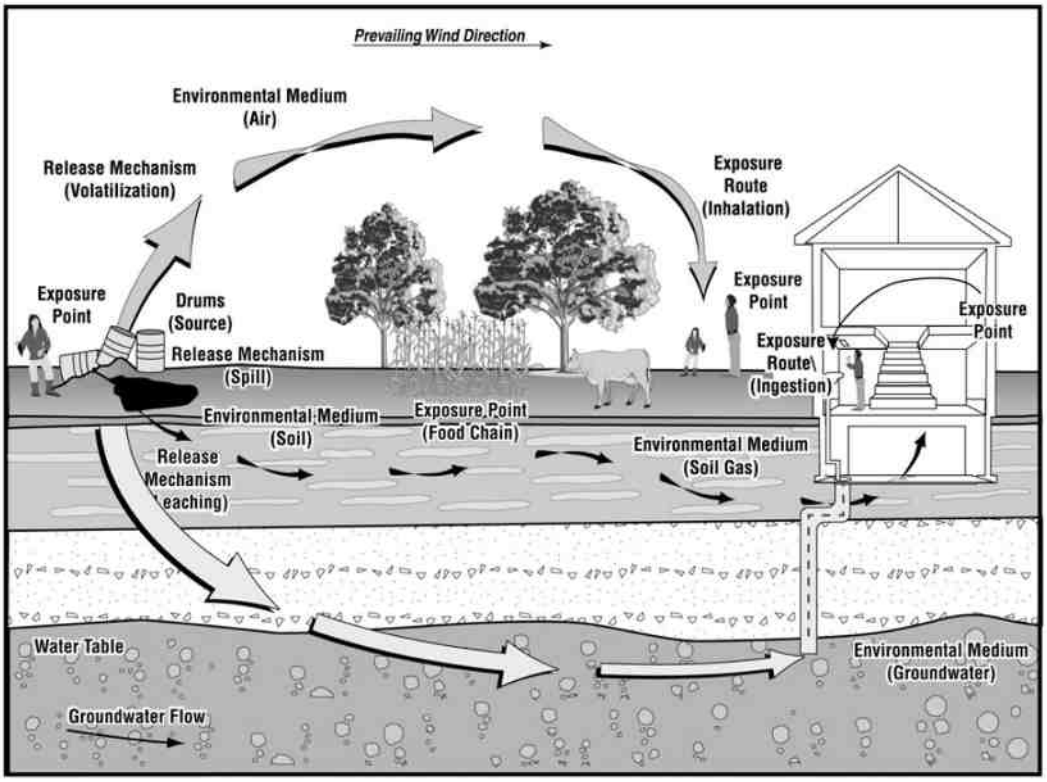
Example of Preliminary CSM Representation from US EPA July 2011



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			
<u>Bedrock subsurface</u>					
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

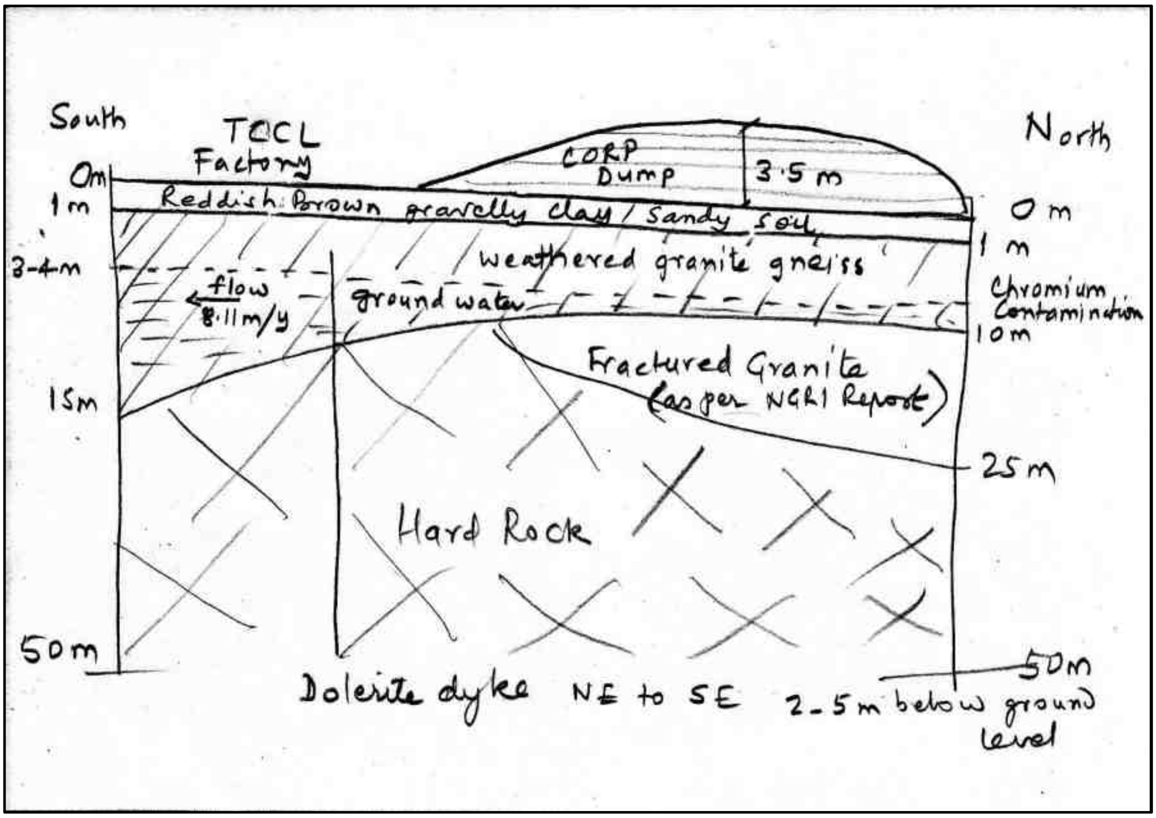
permeable		concentration decreases from average 200mg/kg at 1m depth to less than 50mg/kg at 5m depth	October 2008		site
Porosity		spreading of contaminants: pathway layout			
Weathering:					
thickness of weathered layer		spreading of contaminants: pathway layout			
10 to 15m	Weathered Granite gneiss	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 Overview of techniques for site investigation

Volume III-2.2-ii
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-ii-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-ii-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-ii-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-ii.1

Figure III-2.2-ii.1a and 1b: Example of Ground Penetrating Radar

Figure III-2.2-ii.2: Example of PID Photo-Ionisation Detector

Figure III-2.2-ii.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

Hand held techniques

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-ii.4a Example of soil sampling with shovel

Figure III-2.2-ii.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-ii.5a Example of augers (left) and handles (right)

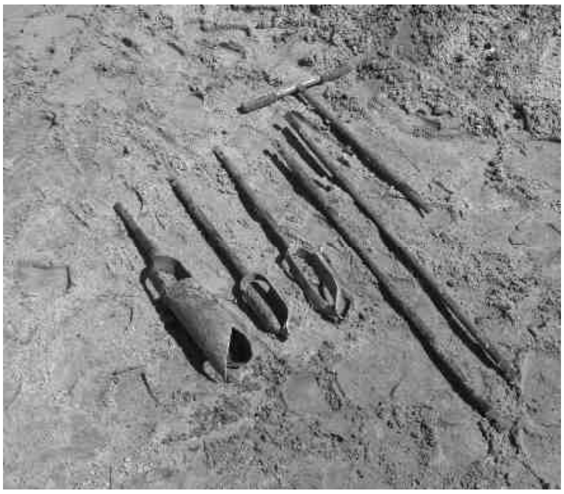


Figure III-2.2-ii.5b Example of augers. From left to right: Riverside (gravel, debris), auger (sand), Edelman auger

Figure III-2.2-ii.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.

Figure III-2.2-ii.1. Example of soil sampling with tube

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.

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-ii.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-ii.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-ii.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-ii.9a Example of hand pulsing, using tripod and steel casing

Figure III-2.2-ii.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-ii 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-ii.11a Auger drill

Figure III-2.2-ii.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-ii.12a and 12b: Examples of power driven displacement drilling system

Figure III-2.2-ii.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.

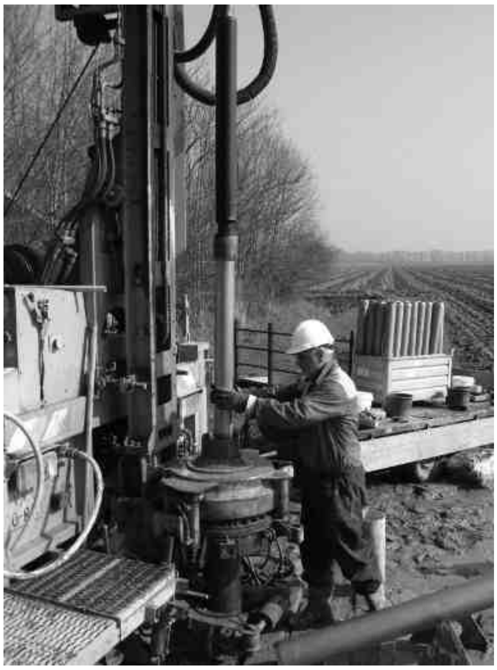


Figure III-2.2-ii.13a, 13b and 13c: Examples of cased auger/pulse drill

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-ii.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-ii.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-ii.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.

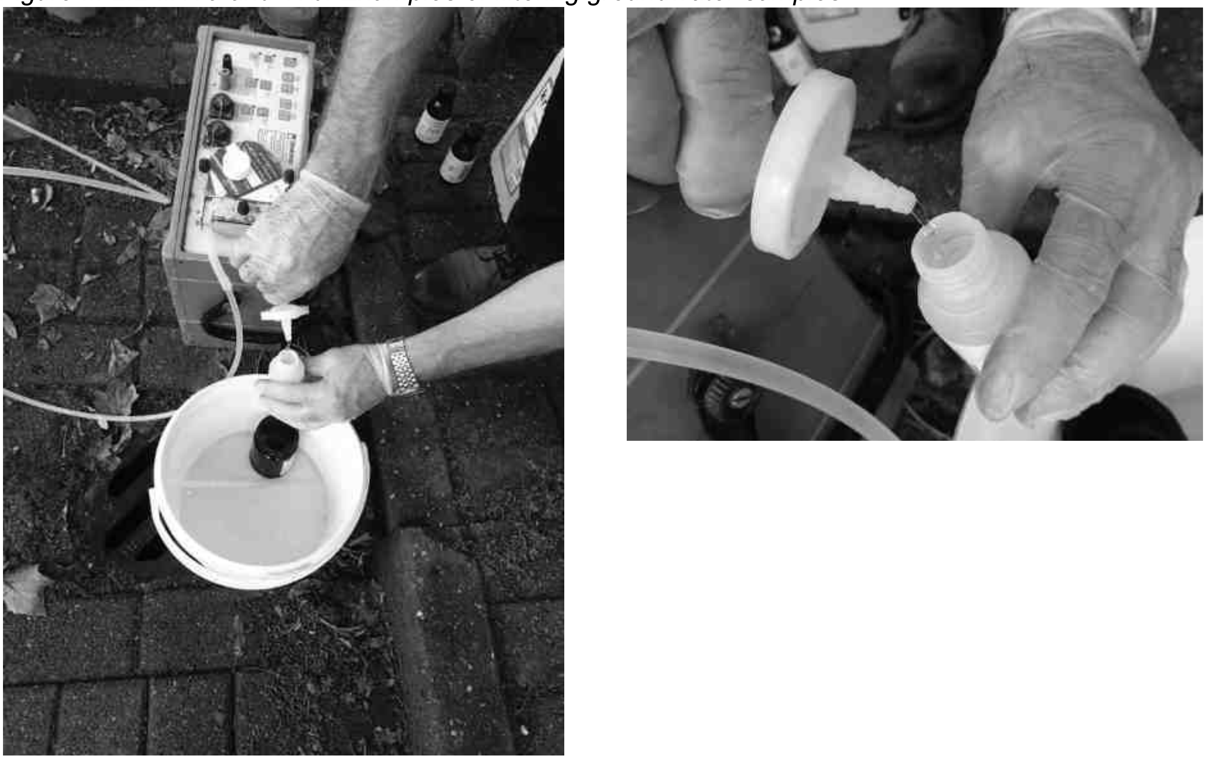
Figure III-2.2-ii.16a and 16b: Examples of ball valve pump

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-ii.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-ii.18: Transparent material piston drill

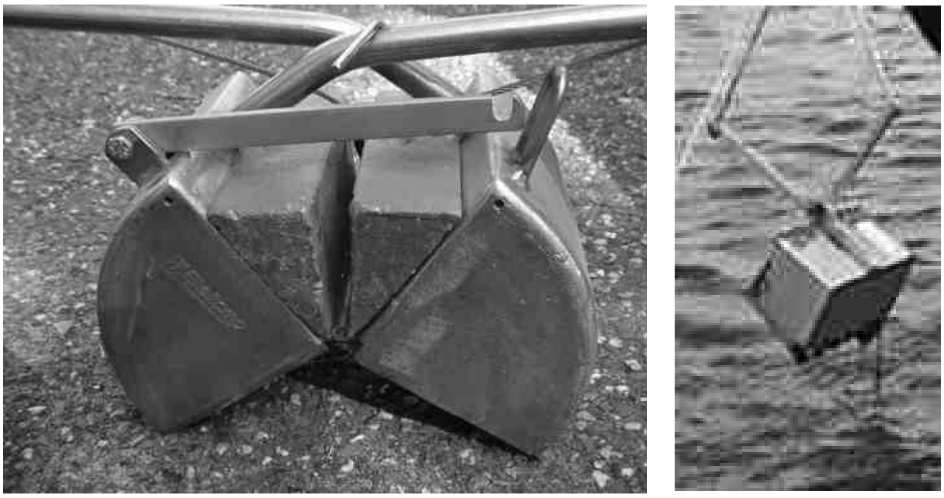
Sediment core sampler

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-ii.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.

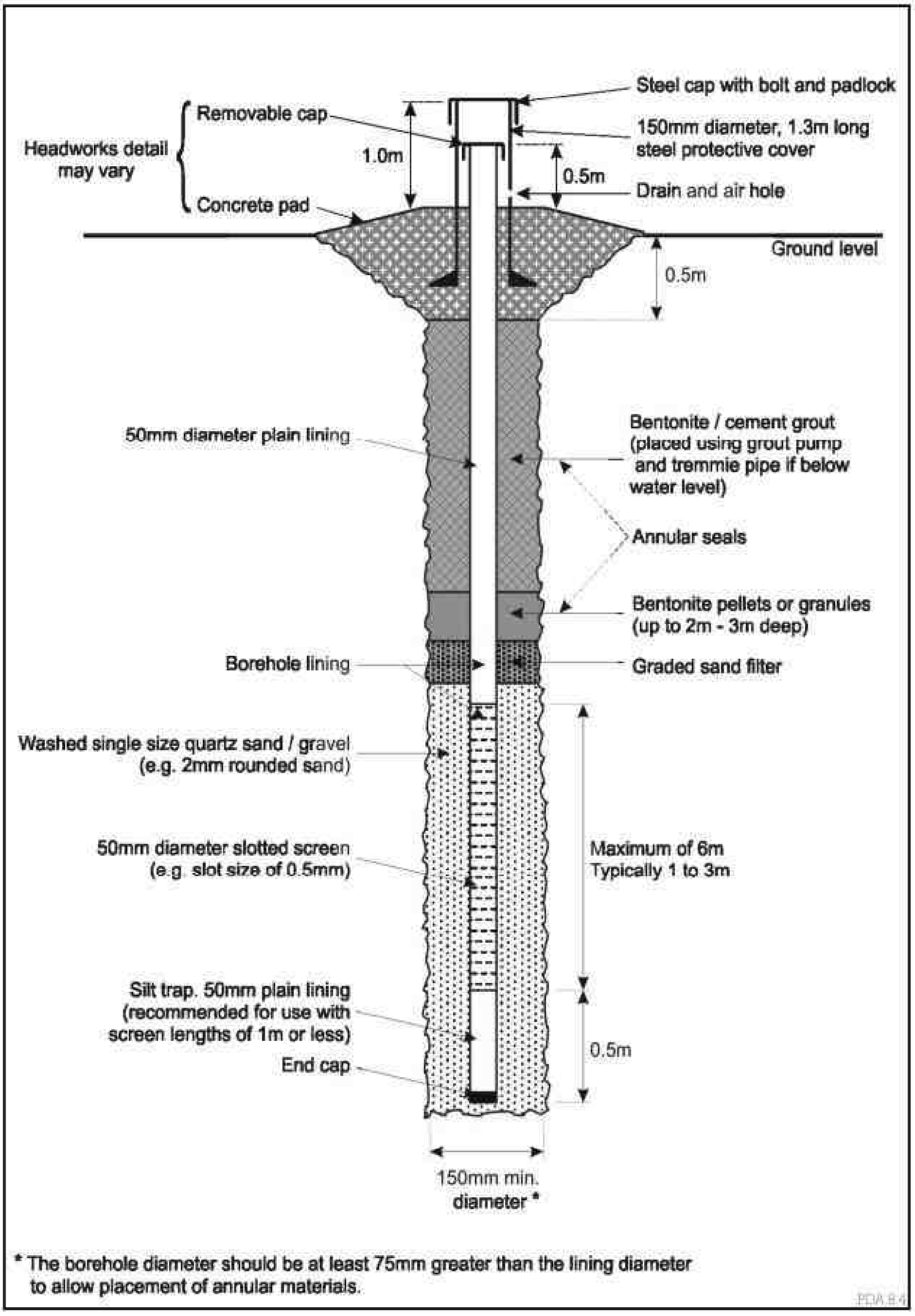
Figure III-2.2-ii.20a and 20b: Examples of grabbers



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.

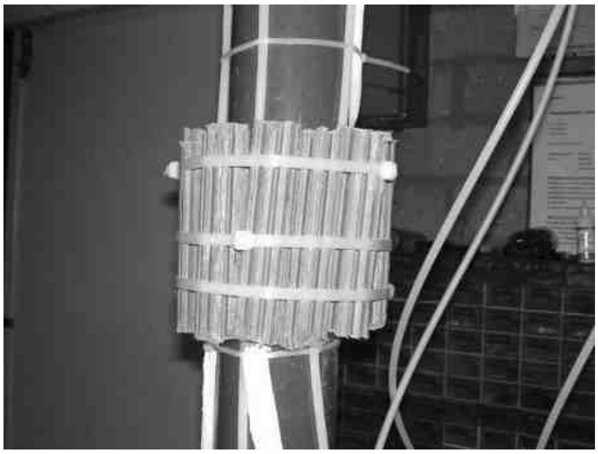
Figure III-2.2-ii.21: Example of generic groundwater well design



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-ii.22 a and b respectively.

Figure III-2.2-ii.22a: Bentonite pellets

Figure III-2.2-ii.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-ii.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-ii.24a-d below.

Figure III-2.2-ii.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-ii.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-ii.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-ii.25a and b below.

Figure III-2.2-ii.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-ii.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 m³ polluted ground, including asbestos and admixtures of debris from 0.4 to 0.8 m depth: 120 m³ contaminated soil, asbestos is not suspected, soil admixtures of foreign material. Volume weight is unknown so the calculation from m³ 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 flow rates;
- presence and proximity of downgradient seeps, springs, or caves;
- fractures or other preferred flow 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 biomagnification 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 fish 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 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. The following internationally widely used models are presented and discussed below:

- CLEA
- RBCA
- RISC5
- CSOIL
- 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.

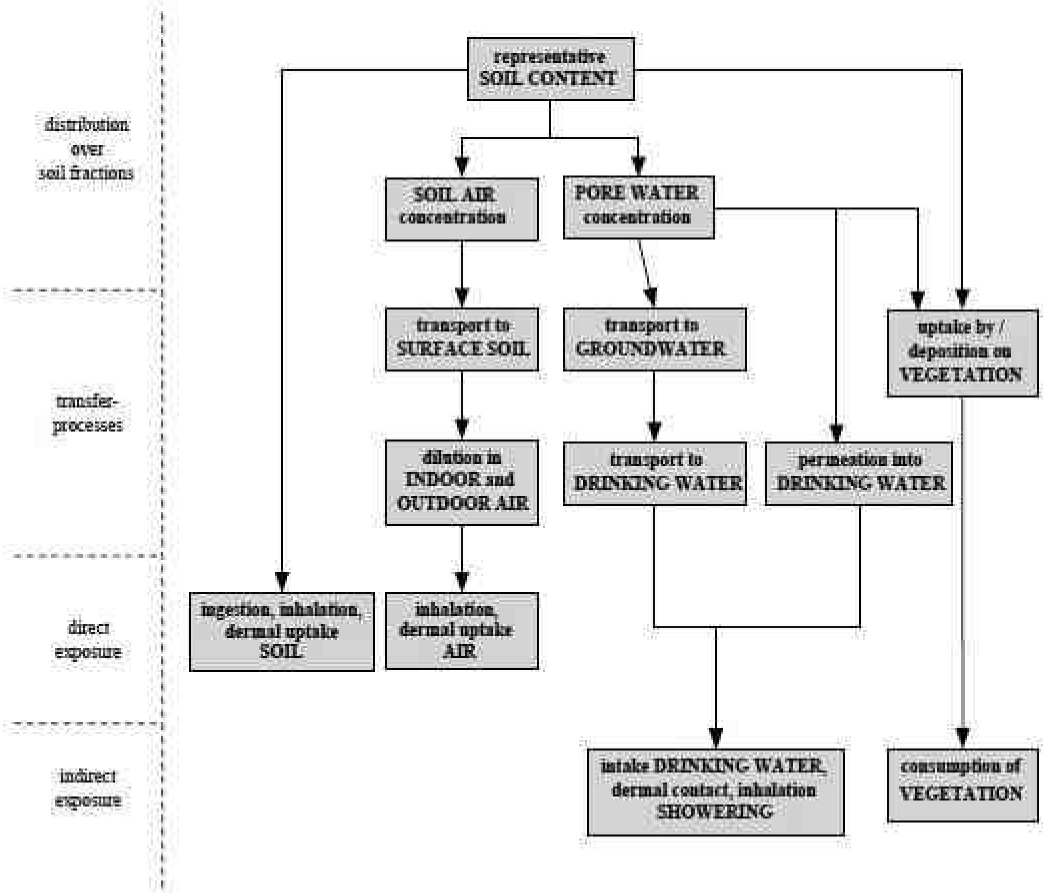


Diagram showing the exposure routes of the model, CSOIL 2000 (RIVM, 2007).

Controlled Waters
Two models are used in the UK to assessment risk water resources. Both are based on guidance provided by the Environment Agency and are described below.

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.

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:

- http://www.environment-agency.gov.uk/research/planning/40385.aspx
  Link to information and examples UK

- http://www.on.ec.gc.ca/pollution/ecnpd/tabs/tab16-e.html
  link to Technical Assistance Bulletin nr 16 on Risk Assessment-Exposure Model, Toxicity analysis and Evaluation, Canada

- http://www.epa.gov/risk_assessment/guidance.htm
  link to information and examples US

- http://www.unido.org/what-we-do/environment/capacity-building-for-the-implementation-of-multilateral-environmental-agreements/the-stockholm-convention/e-learning/unido-contaminated-site-investigation-and-management-toolkit.html
  link to toolkit UNIDO

Assessing risks of persistent organic pollutants, 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)*				*Applicability substances*									
			Source	*Pathway*	*Receptor*	*Applicable media*	*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.

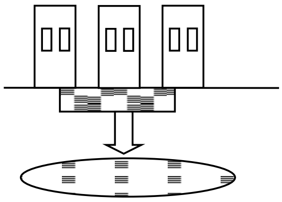
It should be noted that feedback from the Client and end users is crucial to determine whether or not to include the more creative remediation options in the Guidance document.

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

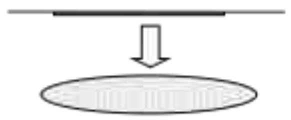
Receptor:
• Treatment of well water to meet drinking water standards or alternative water source
• Imposed limits to site use (e.g. no unauthorized digging, no wells)

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)

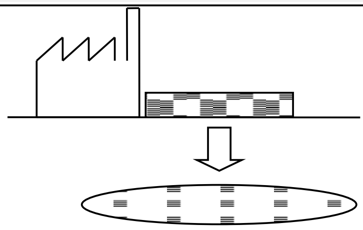
Specific conditions or alternative approaches

- 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.

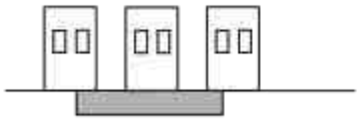
Receptor:
- Goverment imposed limits to site use (e.g. fencing, no unauthorized access)

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.

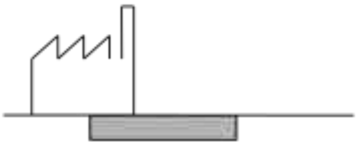
Receptor:
- Imposed limits to site use (e.g. no unauthorized digging)

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.

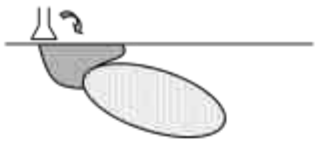
Receptor:
• Imposed limits to site use (e.g. no unauthorized digging)

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)

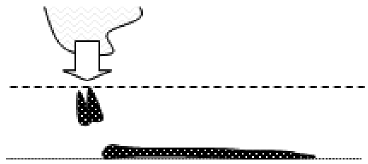
Specific conditions or alternative approaches

- 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

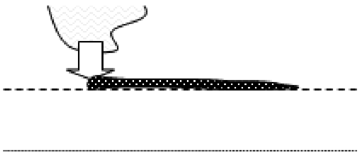
Specific conditions or alternative approaches

- 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)

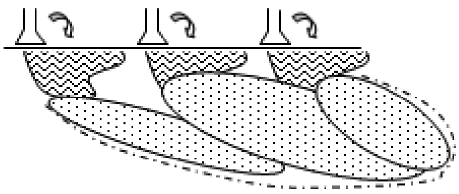
Specific conditions or alternative approaches

- 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.

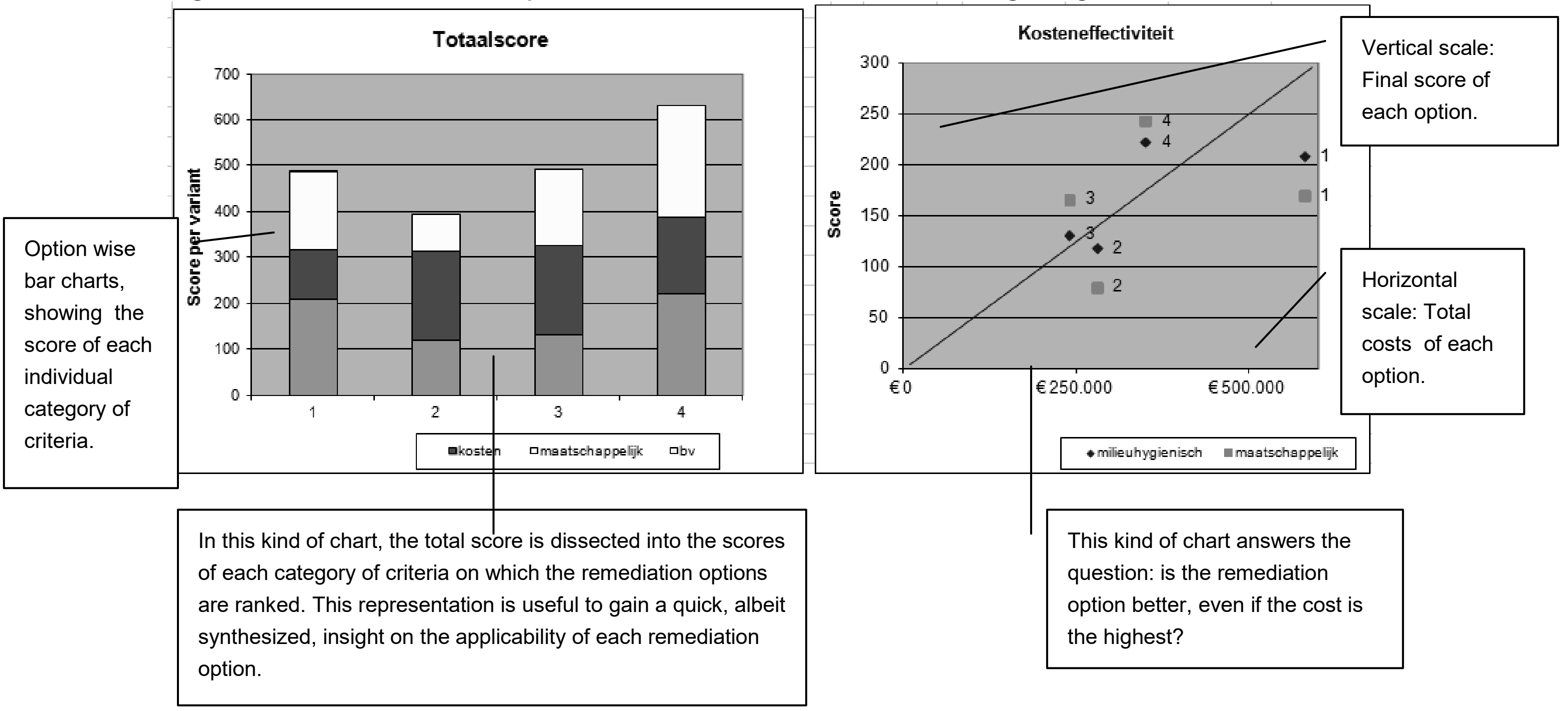
Description of aspects to be ranked.

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



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.

$$SR = \sum_{1}^{n}\left(\left(Benefit_{environment} - Cost_{environment}\right) + \left(Benefit_{society} - Cost_{society}\right) + \left(Benefit_{economy} - Cost_{economy}\right)\right)$$

- 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.