Reference Document

on

Identification, Inspection and Assessment of Contaminated Sites

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

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Central Pollution Control Board
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1.1 Introduction

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

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

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

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

1.2 Waste Vs Soil contamination

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

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

Underwater soil is usually referred as 'sediment'.

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

1.3 Typology of Contaminated Sites

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

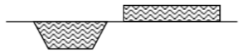
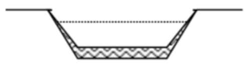
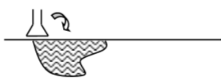
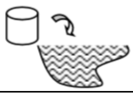
Source related;
- **Type S-1** **:** Land bound solid phase contamination
- **Type S-2** **:** Water bound sediments solid phase contamination
- **Type L-1** **:** Land bound liquid phase contamination

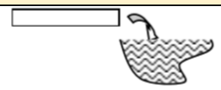
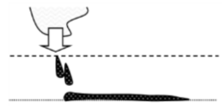
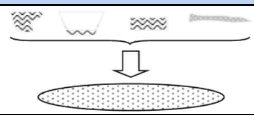
Pathway related;
- **Type P-1** : NAPL contaminants in soil (Non Aqueous Phase Liquids)
- **Type P-2** : Groundwater contamination

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

Table-1: Typology of Contaminated Sites

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

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

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

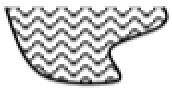
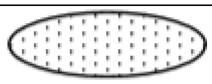
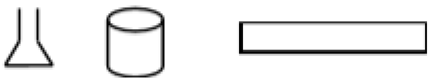
* *Contaminated material may include wastes in Schedule I or the constituents listed in Schedule II of HOWM Rules, 2016. It shall also include constituents listed for screening of contaminated soils as per the guidance document or notification issued by MoEF&CC.*

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

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

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

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

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

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Chapter-2

Identification & Verification of Probable Contaminated Sites

2.1 Introduction

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

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

2.2 Verification Activities

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

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

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

- Visual observation of the site conditions or attendant contaminant sources;
- Visual observation of manufacturing or other operations known to have used or emitted a particularly hazardous contaminant;
- Observed adverse effects in humans, flora & fauna presumably caused by the proximity to the site;

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

The evaluation is visualized in the flowchart below:

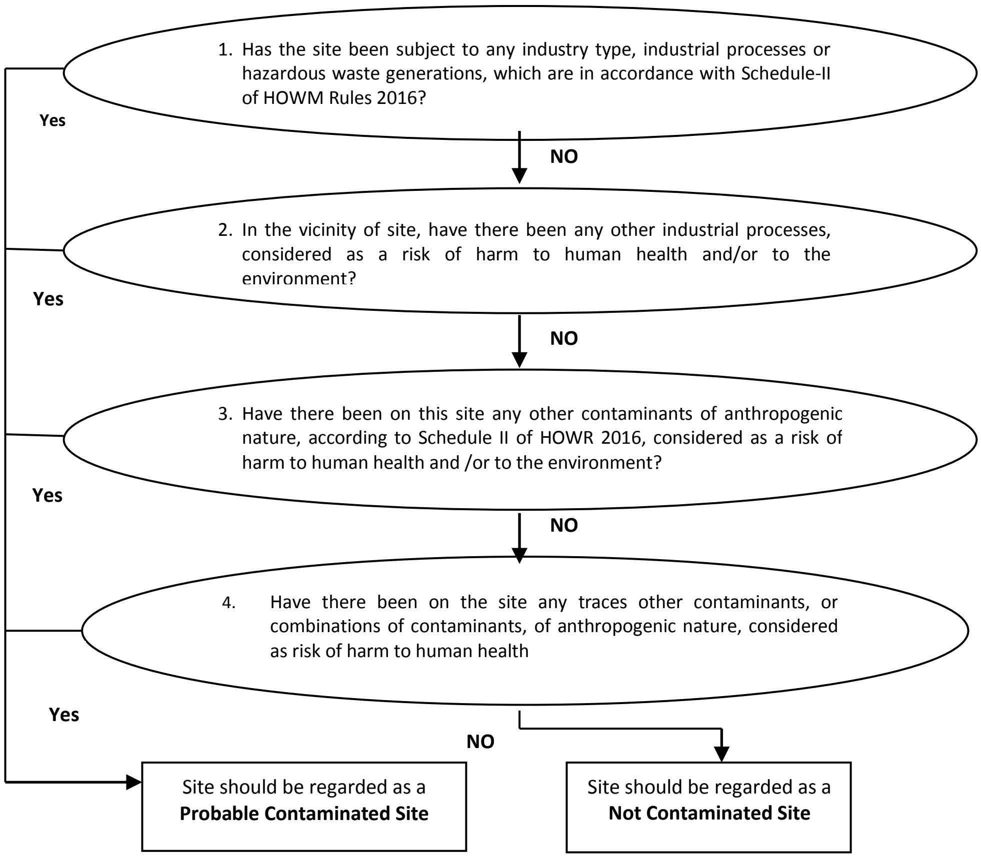

Figure-1.1: Flowchart for evaluation of probably contaminated site

2.3 Outcome

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

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Chapter-3

Preliminary Site Investigation

3.1 Introduction

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

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

3.2 Objectives

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

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

3.3 Activities during Preliminary Site Investigation

i) Desk study

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

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

ii) Site inspection

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

iii) Investigation strategy

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

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

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

a) Sampling pattern

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

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

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

- **Determination of background levels:**

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

- **Determination of contamination levels:**

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

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

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

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

- **Groundwater sampling and analysis:**

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

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

- **Sediment sampling:**
  (i) To collect a sediment sample from a water body or other surface water conveyance, following methods can be used:
    - Scoops and spoons
    - Dredges (Ponar, Young)

  (ii) Samples will keep in several pp-zipped packs/ wide mouth glass bottles.
  (iii) If the total VOC concentration in the sediment is expected to be less than 200 µg/kg, the samples may be collected directly with the sampler and the sample must be placed in the sample container (40 ml pre-prepared vial*) immediately to reduce volatilization losses.

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

- **Quality assurance/Quality control:**

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

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

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

c) Parameters for laboratory testing

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

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

iv) Fieldwork, sampling and testing

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

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

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

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

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

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

v) Comparing testing results with levels/standards

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

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

vi) Reporting and review

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

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

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

3.4 Outcome

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

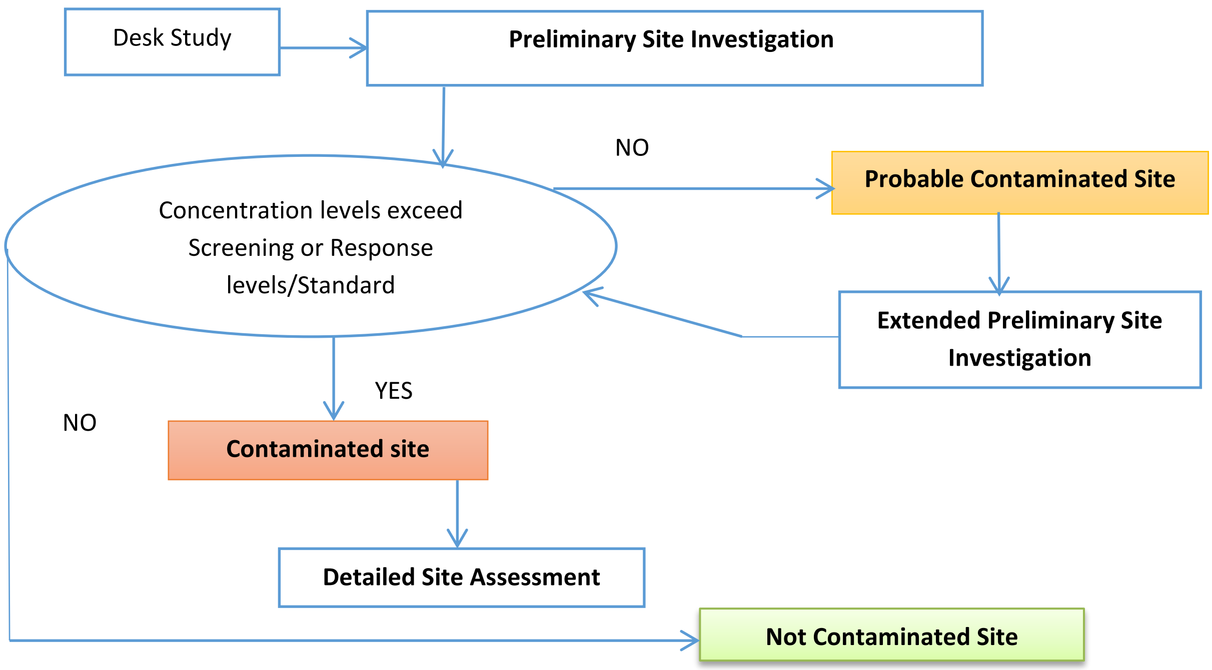


Figure-3.1: Flowchart for Identification & Assessment of site investigation

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

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

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

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

Signature of the Inspecting Officer(s)

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

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

Note:

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

Chapter-4

Sampling Tools and Techniques for site investigation

4.1 Introduction

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

4.2 Screening Equipment

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

4.3 Soil, Sediment and Ground Water Sample Collection Tools

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

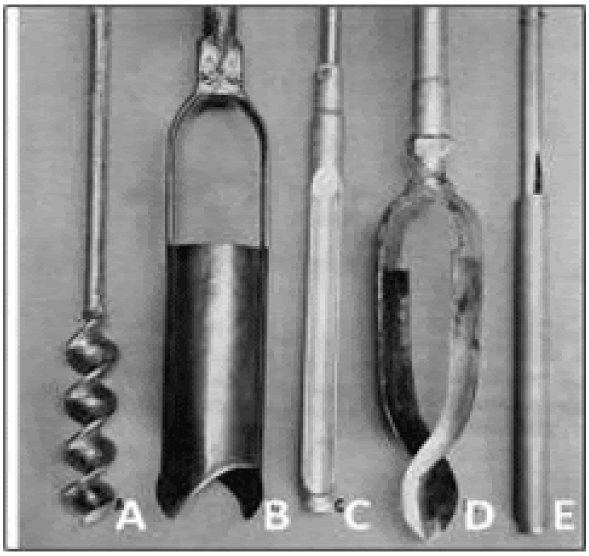
- Hand held techniques
  - Scoops, spoons, and shovels
  - Augers (including split auger)
  - Tube
  - Gouge
  - Thin-walled core samplers
- Power driven drill techniques
  - Screw drilling system: hollow auger drill
  - Screw drilling system: auger drill
  - Displacement drilling system
  - Cased auger/pulse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

<u>(a) Manual techniques for soil sampling</u>

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

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

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

Example of augers with handle	Example of augers
	

Examples of soil sampling with Edelman auger		
		

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

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

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

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

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

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

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

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

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

- **Drill-techniques for soil sampling**

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

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

Hollow auger drill	Machine driven auger drill
	 

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

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

Examples of Power Driven Displacement Drilling System	
	

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

<table>
<tr><td colspan="6">Examples of Auger Drill</td></tr>
<tr><td colspan="2">Manual auger drilling</td><td colspan="2">Machine auger drilling</td><td colspan="2">Cased auger drilling</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">Examples of Cased Auger Drill required for Hard ground and rock drilling</td></tr>
<tr><td colspan="3"></td><td colspan="3">
</td></tr>
</table>

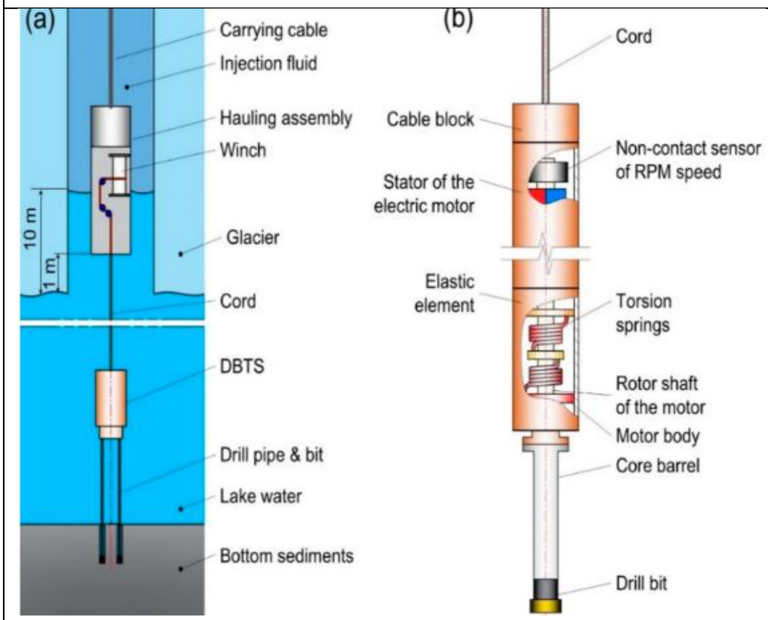
(b) Sediment sampling collection tools

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

- Piston drill
- Sediment core-sampler
- Grabbers

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

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

Transparent material piston drill	Sediment core sampler
	

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

Examples of grabbers	
	

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

Example of tool to detect sediment level	
	

(c) Groundwater sampling collection tools

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

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

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

Suction lift pump	Submersible Pump	Bailer sampler
		

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

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

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

Filtering of groundwater samples

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

(d) Construction of Monitoring Wells

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

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

Monitoring Wells	
	

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

(A) Key principles of constructing monitoring well are;

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

(B) Construction, specifications and precautions:

(i) Properly decontaminate well construction materials prior to installation

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

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

(iv) Use bottom caps or end plugs

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

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

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

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

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

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

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

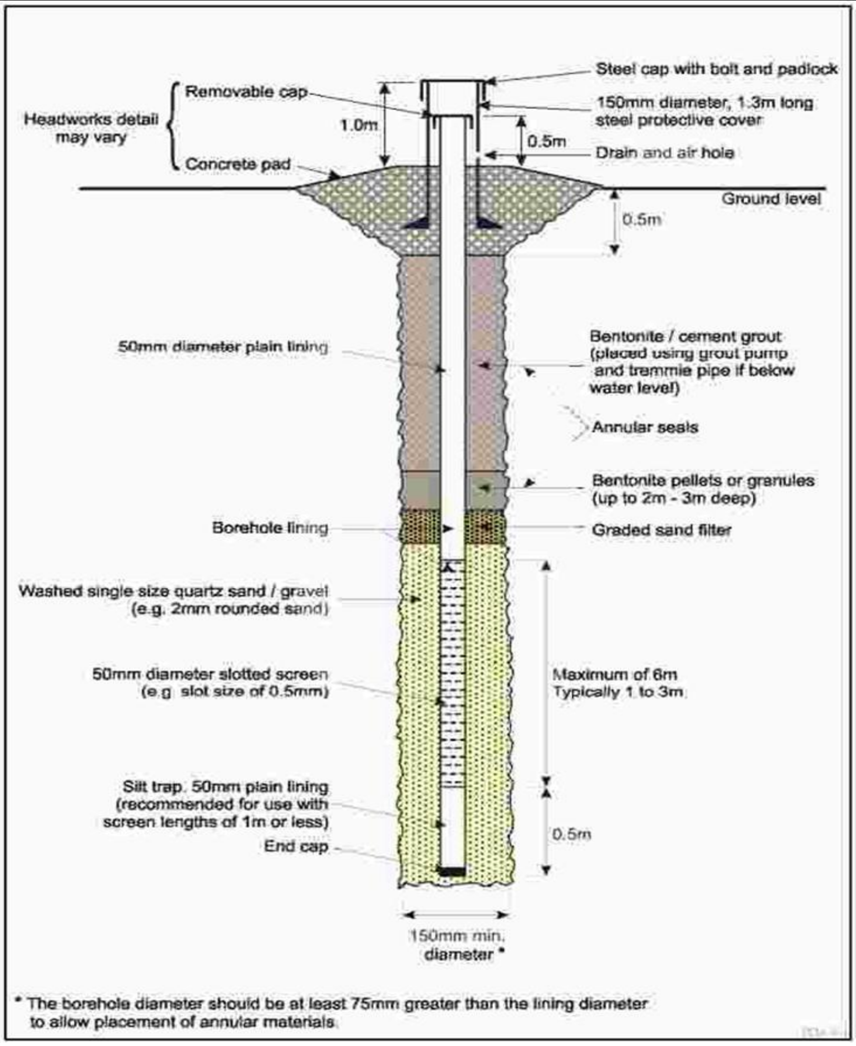
(xii) Add drilling mud to stabilize the hole or control down-hole fluid losses, use only high yield sodium bentonite clay free of all organic polymer additives.

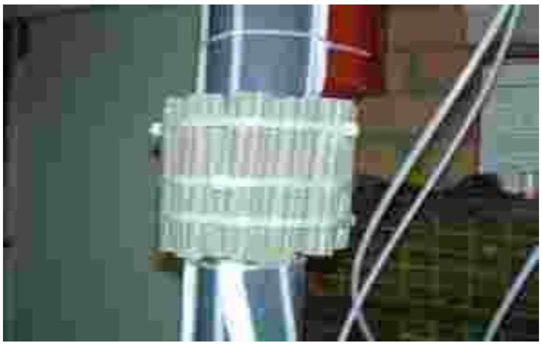
(xiii) Properly decontaminate all equipment placed into the well by steam cleaning, high-pressure hot water, or similar methods between well installations.

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

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

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

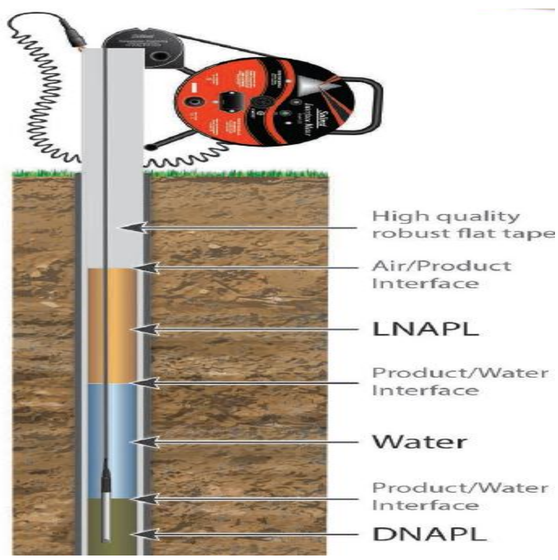
Example of generic groundwater well design


Bentonite pellets	Bentonite plug
	

(e) Groundwater level measuring device

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

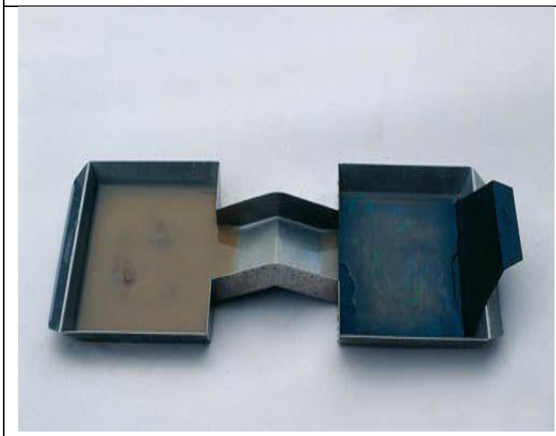
Examples of groundwater level measuring tools



(f) Oil water observation tool

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

Oil-water detection pan



(g) Samples preservation

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

Sample cooling methods	
	Cooling gel packs 

4.2 Outcome

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

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