BEFORE THE NATIONAL GREEN TRIBUNAL

SOUTHERN BENCH CHENNAI

Original Application No. 186 OF 2020 (SZ)

IN THE MATTER OF:

Tribunal on its own motion - SUO MOTU Based on the News item in The New Sunday Express Newspaper Dated: 20.07.2020, "Ranipet Residents health at risk due to Pollution; Chromium waste killing agriculture in Ranipet Poses long-term health risks."

... Applicant

Versus

Union of India Ministry of Environment, Forests and Climate Change, New Delhi and Others

… Respondents

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H.D. [signature]

DEPONENT

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Place: Chennai
Date : 27.05.2022

Report of CPCB in compliance of Hon'ble National Green Tribunal (Southern Zone, Chennai), order dated 17.05.2022 in OA No. 186/2020 in the matter of Tribunal on its own motion - SUO MOTU Based on the News item in The New Sunday Express Newspaper Dated: 20.07.2020, "Ranipet Residents health at risk due to Pollution; Chromium waste killing agriculture in Ranipet Poses long-term health risks" Vs. Union of India and others

Background

The Hon'ble National Green Tribunal, Southern Zone, Chennai in its order dated 17.05.2022 stated & directed CPCB as follows;

"… 4. They have only mentioned about the interim remediation measures, for which, the Detailed Project Report (DPR) has been prepared. They have not suggested the final remediation measures. They cannot proceed with the capping of the Chromium waste in affected areas, as capping of even solid waste – legacy waste is not permitted, we do not think that it will be a permissible activity, as Chromium being a hazardous substance and carcinogenic in nature which may have great impact, if it is not removed from the area and that area has been further remediated.

5. So, the Central Pollution Control Board is directed to come with a final remediation measure by which the Chromium contaminated site can be properly remediated and restored to its original position. Other measures that have been provided are only in respect of existing units which are committing violation. This is already an area which has been contaminated by Chromium deposit already which has to be remediated, without which the life of the people cannot be brought to normalcy in that area…"

Hon'ble Tribunal directed to file their respective reports to this Tribunal **on or before 31.05.2022**

Action Taken by CPCB

In compliance of aforesaid order of the Hon'ble NGT, it is submitted that Action Taken by CPCB regarding preparation of Detailed Project Report (DPR) for remediation of chromium contaminated area at Ranipet, Tamil Nadu, is outlined as below:

a. The MoEF&CC, has identified CPCB as a Project Implementing Agency for 'Remediation of 12 priority hazardous waste contaminated areas. The first phase of the project was envisaged for preparation of Detailed Project Reports (DPRs) for remediation of said 12 contaminated areas including Tamilnadu Chromate and Chemical Ltd (TCCL) contaminated area at Ranipet, Tamil Nadu.

b. Detailed site investigation followed by Human Health Risk Assessment (HHRA) was carried out as part of the study to derive site specific remediation target levels (SSTLs) for remediation.

c. The aforesaid area was visited by Technical Expert Committee (hereinafter referred to as TEC) constituted by CPCB along with the representatives of CPCB, TNPCB and CPCB's Consultant on 13.03.2017. Subsequently, in the 9th meeting of TEC had reviewed the technologies for remediation of said contaminated area. Further, TEC in its 13th meeting held on 02.07.2018 recommended the technologies for remediation of said contaminated area and the same had been accepted by Project Steering Committee (PSC) under the chairmanship of Chairman, CPCB.

d. CPCB completed DPR for remediation of aforesaid chromium contaminated area at Ranipet based on detailed site assessment including risk assessment studies. CPCB vide letter dated 11.01.2019 forwarded the final DPR to TNPCB with request to take up remediation works as per the said DPR. Further, a template of bid document was forwarded to State Government and TNPCB vide CPCB letter dated 13.02.2019 for execution of remediation works.

e. As per the DPR, estimated cost for full scale remediation of contaminated area at Ranipet and the adjoining areas of TCCL site is Rs. 206 crore and apart from this, a groundwater remediation system is required to be operated for about 10 - 15 years at annual operating cost of about Rs. 10 - 15 crore. The remediation technologies with estimated remediation cost are as follows:

i. Excavation, treatment and disposal of contaminated soil and waste at On-site secured landfill (SLF) is about Rs. 194 crore, and
ii. Groundwater remediation by installing abstraction system (pump and treat system) along with a common water treatment plant for chromium contaminated water is about Rs. 12 crore.

Note: *The above remediation cost was estimated during 2018-19. However, the estimated remediation cost may be escalated.*

Outlines of the findings of the site investigation, human health risk assessment study carried out under NCEF project including technology screening, the approach for remediation of contaminated soil, sediment, surface water & groundwater both at on-site and off-site of TCCL area at Ranipet, Tamil Nadu is annexed at **Annexure - I**.

Recommendations

It is humbly submitted that the recommendations for execution of remediation works at chromium contaminated area, Ranipet, Tamil Nadu are as follows:

i. Remediation work shall be executed as per the DPR by State Government through Responsible party and the same shall be executed as per authorization and supervision of TNPCB. TNPCB or State Government may also engage any competent consultant to monitor and verify the said works.

ii. In compliance of Hon'ble NGT (PB) in OA No. 804/2017 titled as Rajiv Naryan Vs. Union of India & Ors, TNPCB may constitute State Level Monitoring Committee (SLMC) to monitor and supervise the remediation works executed by Responsible party.

iii. CPCB may provide technical assistance and also verify the remediation works as and when required.

Annexure-I

Summary of the Detailed Project Report (DPR) for Remediation of TCCL chromium contaminated area at Ranipet, Vellore, Tamil Nadu

1. Site Location & Study Area

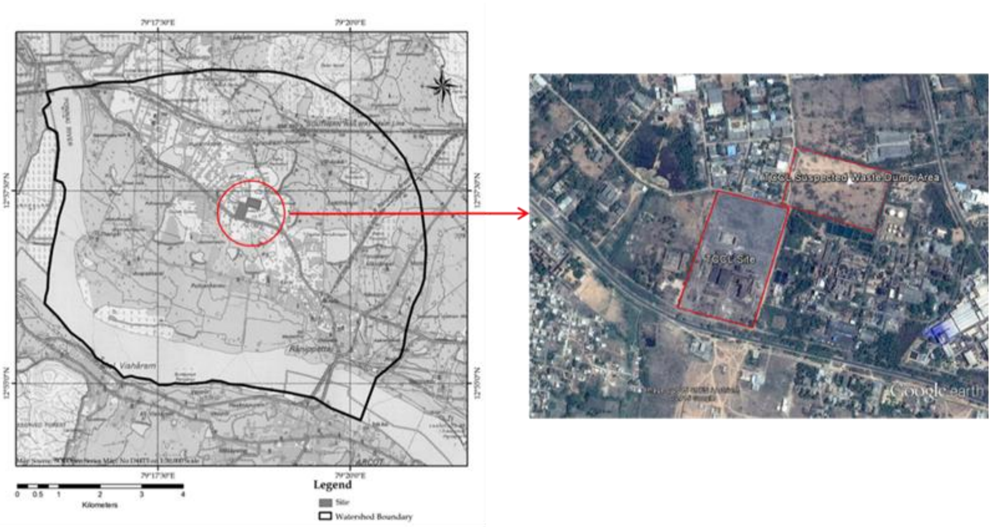
M/s Tamil Nadu Chromates and Chemicals Limited (TCCL), situated at SIPCOT Industrial Estate, Ranipet, Vellore, Tamil Nadu generated and disposed off huge quantity of hexavalent chromium bearing chromite ore processing residue on open land during its about 25 years of operation from 1976 to 2001. The unscientific means of storage/disposal of hazardous waste at TCCL premises resulted in leaching of hexavalent chromium from the dumpsite, percolation of leachate through sub-surface starta and widespread contamination of soil and groundwater in the nearby areas. Another undeveloped land parcel identified located immediately to the northeast of the TCCL Site was also identified as “TCCL Suspected Waste Dump Area (TCCL - SWDA)”.

The total area for TCCL Site is approximately 18.27 acres (73,916 m^2), and that of TCCL-SWDA is approximately 12.63 acres (51,108 m^2).

The entire micro-watershed in which the Site is located is considered as the Study area. The Study area (5.93 km^2) is located between 12º55’2.13” N, 79º 16’45” E in the North and 12º59’5”N, 79º18’22” E in the South, in Vellore, Tamil Nadu, and falls in Survey of India Top-sheet number D44T5.

The general location of the TCCL and the study area is shown in Figure below:

Figure-1: Ranipet Study Area and Site



Study Area Site

2. Summary of the Site Investigation

The objective of the Site investigation (i.e. Step 2 and Step 3 of the project) was to delineate the contamination in soil, groundwater, sediment, surface water and waste at the TCCL site as well as the micro-watershed, within which the TCCL site is located. To characterize the nature and extent of the contamination, Sampling and Analysis Plan (SAP) was developed based on the findings from Step 2 (i.e. Preliminary Site Investigations) conducted at the subject site in Ranipet.

2.1 Analytical Plan

Based on SAP; soil, groundwater, surface water and sediment samples were analysed for the following suite:

- Chromium (as Total Chromium and Hexavalent Chromium);
- Iron (as total Ferrous and Ferric);
- Chloride as Cl; and
- Sulphate as SO_4.

Twenty (20) percent of samples were also analysed for the following brownfield suite:

- Metal Suite: Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Total Chromium (Cr), Chromium VI, Cobalt (Co), Copper (Cu), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Vanadium (V) and Zinc (Zn);
- 56 Volatile Organic Compounds;
- 114 Semi-Volatile Organic Compounds; and
- Total Petroleum Hydrocarbons (C6- C36)

Based on the SAP developed, following is below:

On-site data:

Soil: A total of four (04) soil samples were collected from three (03) locations within the TCCL Site, at near surface and below surface depth.

Groundwater: Groundwater samples were collected from four (4) existing monitoring wells located within the TCCL facility and ten (10) monitoring wells installed during the Step 3 investigation.

Off-site data:

Soil: A total of twenty (20) samples were collected from ten (10) off-site soil locations, including three (3) QA/QC samples. Eight (08) samples were also analysed for brownfield suite.

Groundwater: A total of thirty-five (35) groundwater monitoring wells were sampled including three (3) installed during Step 2, one (1) existing well near the CETP sludge storage area, nineteen (19) abstraction wells across the study area in the surrounding villages and twelve (12) newly installed monitoring wells.

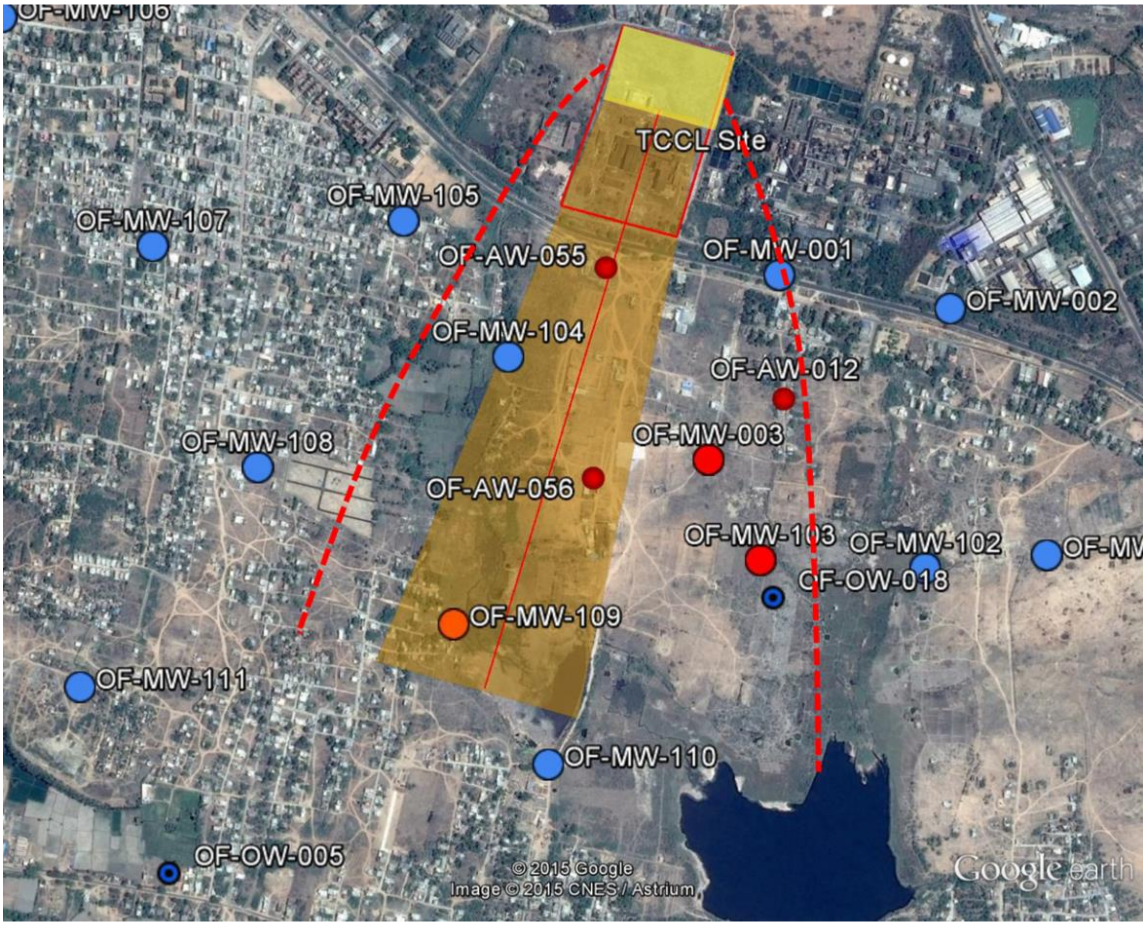
Surface Water and Sediment: A total of fourteen (14) surface water samples, thirteen (13) off-site and one (01) on-site and twelve (12) sediment samples off-site were collected to the north and south of the site.

Based on the investigations, some of the key findings are as below:

- In total, 63 soil boreholes, 30 monitoring wells and 12 sediment boreholes were drilled and sampled, and 5 existing open wells, 2 hand pumps, eleven (11) bore water and 14 surface water samples were collected and sampled;
- The main source of contamination is the waste dump located in the northern portion of the Site;
- Secondary sources of contamination may be attributed to abandoned CETP pumping wells located north of Site;
- The contaminants of potential concern; i.e. Total Chromium and Hexavalent Chromium, have been identified in soils, groundwater and surface waters. The data indicates that the Total and Hexavalent Chromium contamination is mainly limited to the on-site waste dump area. The Hexavalent Chromium groundwater contamination plume is migrating south of site; whereas surface water impacts are seen in the site's effluent drains leading off-site; and
- There is active contamination in open drains due to contaminated run-off waters/wastewaters from the TCCL site.
- None of the sediment samples reported Hexavalent Chromium above its Limit of Reporting (LoR) but Total Chromium was detected in concentrations above the reference criteria.
- During the Step 3 investigations, cluster wells were installed within TCCL premises in the southwest corner of the Site (groundwater flow direction is northeast to southwest) and total and Hexavalent Chromium was reported in groundwater upto a depth of 45 m bgl with maximum concentrations occurring at 30 m bgl;

- In the off-site groundwater sampling locations, the monitoring wells and abstraction wells within 0.5 km south of Site were found to contain total and Hexavalent Chromium concentrations in exceedance of reference levels.
- The monitoring and abstraction wells located off-site which have reported Total and Hexavalent Chromium in concentrations exceeding reference levels are indicated in red in the below Figure-2.

Figure-2: Study Area impact map



Most of the off-site exceedances in groundwater are occurring within the modelled path (or in close proximity) and thus the exceedances are in agreement with the particle tracking model.

At the suspected waste dump Site, historical google satellite imagery showed irregular patches on the land suspected to be waste dump from neighbouring industries. However, with the Step 2 Investigations, possible soil and groundwater contamination was ruled out at the Suspected Waste Dump Site.

2.2 Data Evaluation

a) Data Quality Evaluation

Field duplicates were also collected for quality assessment in samples collected in each matrix (Soil/ Groundwater/ Surface water/Sediment).

The ratio of field duplicates was one (01) duplicate sample per fifteen (15) samples. Following is a summary of the field duplicate samples collected during the study.

- **Soil:** Three (3) duplicate samples were collected from TCCL Site and off-site locations for a total of twenty-four (24) samples.
- **Groundwater:** Five (5) duplicate samples were collected for a total of forty-nine (49) samples.
- **Surface water:** Two (2) surface water samples were collected as duplicate for fourteen (14) surface water samples.
- **Sediment:** Two (2) sediment samples were collected as duplicate for twelve (12) sediment samples.

b) Comparison between Step 2 & Step 3 data

In the comparisons of Step 2 (sampled May 2014) and Step 3 (sampled November 2015) data, the reported concentration trend(s) are mentioned below:

- **Groundwater:** No strong trend was noted between the Step 2 and Step 3 sampling concentrations. However, Total Chromium concentrations were slightly higher than the Step 2 concentration (in monitoring wells as well as abstraction wells); while Hexavalent Chromium concentrations were overall lower in monitoring wells and higher in abstraction wells;
- **Surface water:** Total Chromium concentrations were slightly lower than the Step 2 concentration in most of the samples. Hexavalent Chromium concentrations reported no clear trend;
- **Sediment:** Total Chromium concentrations reported an increase in six (6) samples [and a decrease in five (5) samples]. Hexavalent Chromium was not reported in the sediment samples during Step 2 and Step 3.

2.3 Impact Sources (locations and details) and Migration

Based on the laboratory analytical data, Total and Hexavalent Chromium were the only widespread CoCs identified in the Study Area in all sampled matrices (soil, groundwater, surface water and sediment).

a) Areas of Concern

Based on the laboratory analytical data, the following primary and secondary on-site and off-site source area(s) were identified for Total and Hexavalent Chromium in soil, groundwater and surface water.

Table-1: Source Area(s)

	TCCL Site	Off-Site
Source Areas	– Waste dump area; – Plant buildings; – Plant machinery; – Utilities (ETP)	– Surrounding industries; – CETP; – CETP Pumping wells;
Secondary Matrices	– Leachate (into groundwater); – Soil/Waste;	– Surface water run-off drains; – Soil/ sediment impacted by the surface water run-off; and – Surface water lakes within the Study area

b) Chemicals of Concern (CoCs) Sources

The chemicals exceeding Tier-1 screening criteria are summarised below:

Table-2: Analytes exceeding Tier-1 screening criteria across matrices

Soil	Groundwater*	Surface water	Sediment
Chromium	Chromium	Chromium	Chromium
Chromium (III)	Hexavalent Chromium	Hexavalent Chromium	Copper
Ferrous Iron	Sulfate	4-Chloro-3-methylphenol	Mercury
Iron	Chloride	Aniline	TPH
Iron III, Ferric	Arsenic	TPH	Naphthalene
Nickel	Copper	Naphthalene	
Cobalt	Cadmium		
Copper	Cobalt		
Thallium	Lead		
Vanadium	Manganese		
Zinc	Zinc		
	Cyclohexane		
	Toluene		
	o-Cresol		
	p-Cresol		
	TPH		

** The volatile organic compounds (VOCs) reported in groundwater and sediment samples were during Step2 investigations and the same analytes were* ***not*** *reported in Step 3 investigations.*

Table-3: Maximum Concentration found in study area

Analyte	Maximum Concentration	
	Soil (mg/kg)	**Groundwater (mg/L)**
Chromium III	2,09,179	2,939
Chromium VI	5,596	277.62
Cobalt	133	NA
Nickel	772	NA
Vanadium	662	NA
Lead	NA	138
Manganese	NA	2,980
Zinc	NA	452

2.4 On-Site Waste Dump Quantification

The chromium containing waste is primarily dumped in the northern part of the Site. Based on the topographic survey data (carried out during Step 1 i.e. Reconnaissance and Preliminary Assessment), the volume of the entire mound in the northern part of the Site is 1,03,260 m^3 and the mass is 1,38,360 MT (considering bulk density of 1.34 g/cm^3)

Figure-3: Waste Dump Quantity Estimation

During Step 2 investigation, (25 x 25) meters grid was considered and trial pitting was carried out across the TCCL Site. During the trial pitting activities, the following limitations were encountered:

- Trial pitting was carried out upto a maximum depth of 3 m bgl;
- Trial pitting was terminated in the event that groundwater was encountered

Based on the trial pitting activities, the waste dump area is considered to be approximately (200 x 100) meters in the northern portion of the Site. Forty (40) trial pits were excavated within the said area with fourteen (14) trial pits excavated upto 3m bgl. Lithological data was also obtained during the monitoring wells installation within the dump area (maximum depth of 15 m bgl).

Considering the limitations stated above, the following estimate was calculated using a constant depth across the waste dump Site.

Table-4: Estimated Quantification of Waste Dump located within Site

Assumed depth of waste dump	Estimated Volume (m^3)	Estimated Mass (MT)
3 m bgl	65,450	87,701
4 m bgl	87,267	1,16,930
5m bgl	1,09,080	1,46,170

Area = 208m x 143m
Waste material bulk density: 1.34 g/cm^3

3. Risk Assessment Study

3.1 Risk Assessment Objectives

The objective of the Human Health Risk Assessment (HHRA) was to assess whether observed soil, groundwater, surface water and sediment impacts (if any) resulting from the dumping of Chromium-containing wastes at the TCCL Site have the potential to represent a risk to human health under the current and possible future land-use.

3.2 Approach for Screening and Risk Assessment

a) Tier-1 Screening Level Risk Assessment

The results of Preliminary and Detailed investigation are compared with Canadian screening levels, the applicable Indian standards and also the Dutch intervention values (DIVs) for Tier-1 screening. The parameters that exceed the screening levels are identified as chemicals of concern (CoCs). Site specific risk assessment criteria are generated for each of such CoCs for quantitative risk assessment in next step.

b) Tier-2 Screening based on Human Health Risk Assessment:

The objective of the Human Health Risk Assessment (HHRA) was to assess whether observed soil, groundwater, surface water and sediment impacts (if any) resulting from the dumping of Chromium-containing wastes at the TCCL Site have the potential to represent a risk to human health under the current and possible future land-use. This assessment will be used to support decisions on whether the land (including the water bodies) is suitable for the current use or whether additional environmental investigations and/or remediation may be necessary.

A Conceptual Site Model (CSM) is developed to establish potential connections between Source-Pathway-Receptor at the areas of concern and is a key material for quantification of the Human Health Risk Assessment. For exposure to the identified receptors to be considered possible, a mechanism ('pathway') must exist by which contamination from a given source can reach a given receptor. A complete 'source-pathway-receptor' exposure mechanism is referred to as a 'SPR linkage'. The potential SPR linkages are evaluated for completeness based on the existence of:

- A source of chemical contamination;
- A mechanism for release of contaminants from identified sources (e.g. volatilisation into air or dissolution into groundwater);
- A contaminant retention or transport medium (e.g., soil, air, groundwater etc.);
- Potential receptors of contamination (e.g., groundwater, surface water, people); and
- A mechanism for chemical intake by the receptors at the point of exposure (ingestion, dermal contact, inhalation or a combination thereof).

A quantitative Risk Characterisation process is undertaken for the development of site specific target levels (SSTLs). Internationally recognized risk assessment model are used to develop SSTLs. Inputs to this model are several parameters such as toxicological information, body weight of the people exposed, exposure duration, skin surface area, soil type, porosity, standing water thickness, depth to groundwater etc. The quantitative assessment of risk to human health involves the following five main stages:

a. Issue Identification (includes conceptual site model);
b. Exposure Assessment;
c. Hazard Assessment;
d. Risk Characterization; and
e. Uncertainty and Sensitivity Analysis.

Risks associated with non-carcinogenic (threshold) contaminants have been characterised by Hazard Quotients (HQs) and the HQs for multiple exposure pathways and a combination of chemicals have been summed to calculate an overall risk level, or Hazard Index (HI). A hazard index of 1 indicates that the estimated exposure intake is equal to the threshold dose, and means that a significant risk may be present. Thus, a target HI of 1 was used to calculate the SSTLs. Risks associated with carcinogenic contaminants are characterized by an Increased Lifetime Risk of Cancer (ILCR). To calculate the SSTLs an ILCR of greater than 1 in 1,00,000 (10E-05) was considered to be significant.

c) Some Key Inputs and Assumptions

A list of qualitative assumptions while undertaking HHRA for the various receptors has been outlined below:

- Piped water supply is used for drinking and cooking while groundwater is used for domestic purposes
- There is daily contact with groundwater
- Residents are exposed to indoor and outdoor soil dust on a daily basis
- Intrusive maintenance worker and fisherman and herdsmen are also exposed to soil dust within the study area
- There is regular contact with soil for the intrusive maintenance worker
- There is contact with surface water during fishing for fishermen
- Exposure to soil and surface water happens to forearm, hands and legs
- Exposure to sediments happens in the foot, legs and knees
- There may be incidental ingestion of surface water while fishing

In identifying the Chemicals of Potential Concern (CoPCs), of the thirty-five (35) soil samples and thirty (30) groundwater samples (across step 2 and 3) analysed for the entire brownfield suite, the analytes were considered as CoPCs and further modelled for Risk Assessment if more than six (6) samples exceeded the Tier-1 screening criteria.

A Tier-1 Screening Assessment was undertaken of all laboratory analytical data from the Preliminary and Detailed Site Investigations carried out. Based on the laboratory analytical data Total and Hexavalent Chromium were the only widespread CoCs identified in the Study Area in all sampled matrices (soil, groundwater, surface water and sediment). Cobalt, Nickel and Vanadium were reported in exceedance of Tier-1 screening criteria in soil and Lead, Manganese and Zinc view reported in groundwater.

In accordance with best practice, a child was assumed to be the most sensitive receptor in residential areas, whereas an adult was the most sensitive receptor as commercial employees and intrusive maintenance workers.

Depending on the nature of the chemical of concern, impacted medium and receptor, exposure pathways included:

- Inhalation of vapours generated from contaminated media;
- Dermal contact with impacted media;
- Incidental ingestion of impacted media;
- Inhalation of dust particles; and
- Ingestion through consumption of vegetables grown in impacted areas.

d) Site Specific Limitations

Although exposure from consumption of fish was also identified for these receptors. However, the CoPCs identified as significantly bio-accumulating and the use of conservative assumptions input of maximum site-specific concentrations into the model and consideration of direct incidental ingestion and dermal contact to both soil and groundwater by all identified receptors is expected to provide conservative SSTLs also protective of these exposures.

Developed soil and groundwater site-specific target levels (SSTLs) to identify areas that contain impacted soil and groundwater due to the disposal of Chromium-containing industrial wastes and which constitute a human health risk to receptors in the Study Area.

Developed risk-based SSTLs to be protective of each of SPR linkage. The linkages were identified following the framework for carrying out a quantitative health risk assessment as outlined in ASTM (2010), USEPA (1989) and NEPM (1999).

The consolidated laboratory analytical data was re-screened against the most conservative of the derived Tier 2 Risk Assessment model outputs (SSTLs). The results of this screening indicate the area(s) and the media that will require remedial action in order to break the particular SPR linkages at such area(s).

A summary of the Human Health SSTLs is in the tables below:

Table-5: Summary of Human Health SSTLs for Soil (all numbers are in mg/kg)

Soil (mg/kg)	Off-Site Residents (Child)	Off-Site Agricultural Worker/Fisherman (Adult)	On-Site and Off-Site Intrusive Maintenance Worker (Adult)
Chromium III	1,10,000	1,82,000	1,82,000
Chromium VI	128	260	260

Soil (mg/kg)	Off-Site Residents (Child)	Off-Site Agricultural Worker/Fisherman (Adult)	On-Site and Off-Site Intrusive Maintenance Worker (Adult)
Cobalt	160	324	324
Nickel	560	1,390	1,390
Vanadium	690	1,460	1,460

Table-6: Tier-1 screening criteria for soil in mg/kg

Soil (mg/kg)	Canadian Environmental Quality Guidelines **(CEQG) Residential/ Agricultural**	Dutch Intervention Value (DIV) 2012	USEPA 2015 (Residential)
Chromium III	64	180	120,000
Chromium VI	0.4	78	0.3
Cobalt	40	190	23
Nickel	50	100	1500
Vanadium	130	NS	390

None of the off-site soil samples reported Total Chromium concentrations exceeding the SSTLs (1,10,000 mg/kg).

The volume of material (soil and waste) exceeding the SSTL for hexavalent chromium (128 mg/kg) as indicated in the above map is estimated to be 1,35,000 m^3.

None of the off-site soil samples reported Chromium VI concentrations exceeding the SSTLs (128 mg/kg).

Table-7: Summary of Human Health SSTLs for Groundwater (all numbers are in mg/L)

Groundwater (mg/L)	Off-Site Residents (Child)	Off-Site Agricultural Worker/Fisherman (Adult)	On-Site and Off-Site Intrusive Maintenance Worker (Adult)
Chromium III	8.9	46.3	127
Chromium VI	0.0086	0.041	0.687
Lead	0.034	0.162	3.35
Manganese	0.77	3.67	68.4
Zinc	0.48	2.30	44.9

Table-8: Tier-1 screening criteria for groundwater (all numbers are in mg/L)

Soil (mg/kg)	CEQG	DIV	USEPA
Chromium III	0.05	0.03	22
Chromium VI	NS	NS	0.000035

Soil (mg/kg)	CEQG	DIV	USEPA
Lead	0.01	0.075	0.015
Manganese	0.05	NS	0.43
Zinc	5	0.8	6

The most conservative of the SSTL values for Chromium VI, 0.0086 mg/L is lower than the detection limit of 0.02 mg/L for the same. Hence, impact delineation against the Chromium VI SSTL value has not been carried out.

The complete Source-Pathway-Receptor (SPR) Linkages are detailed in Table-9*:* below:

Table-9: Summary of Source-Pathway-Receptor Linkages

Source	Pathway	Receptors			Justification
		Off-Site	Off-Site	On-Site & Off-Site	
		Residents	Fishermen & Herdsmen	Intrusive Maintenance Workers	
Soil (Waste Dumps)	Inhalation of dust/vapours	✓	✓	✓	Not Applicable (NA)
	Incidental ingestion/dermal contact	✓	✓	✓	NA
Secondary source of contamination from Soil (Waste Dump)	Consumption of dairy produce (cattle grazing on waste dump)	✓	✓	✓	NA
Groundwater	Ingestion (Consumption of drinking water)	✓	✓	✓	Maintenance workers are day labourers who do not reside within the study area , hence unlikely to consume groundwater within the study area
	Incidental Ingestion / Dermal contact	✓	✓	✓	NA

Source	Pathway	Receptors			Justification
		Off-Site	Off-Site	On-Site & Off-Site	
		Residents	Fishermen & Herdsmen	Intrusive Maintenance Workers	
Surface water	Incidental ingestion/dermal contact	✓	✓	✓	NA
	Consumption of fish	✓	✓	✓	NA Note: Fish tissue not sampled/ analysed.
Sediments	Dermal contact	✓	✓	✓	NA
	Consumption of fish	✓	✓	✓	NA Note: Fish tissue not sampled/ analysed.

✓ *= SPR linkage complete*
X= *SPR linkage incomplete*

Considering the above detailed SPR linkages, the HHRA was undertaken and Site Specific Target Levels (SSTLs) were derived for each matrix. The SSTLs for soil based Hazard Index (HI) are summarized below;

Table-10: Summary of Human Health SSTLs for Soil based on Hazard Index (HI), Non Cancer (all numbers are in mg/kg)

Soil (mg/kg)	Off-Site Residents (Child)	Off-Site Fishermen and Herdsmen (Adult)	On-Site and Off-Site Intrusive Maintenance Worker (Adult)
Chromium III	1,10,000	1,82,000	1,82,000
Chromium VI	128	260	260
Cobalt	160	324	324
Nickel	560	1,390	1,390
Vanadium	690	1,460	1,460

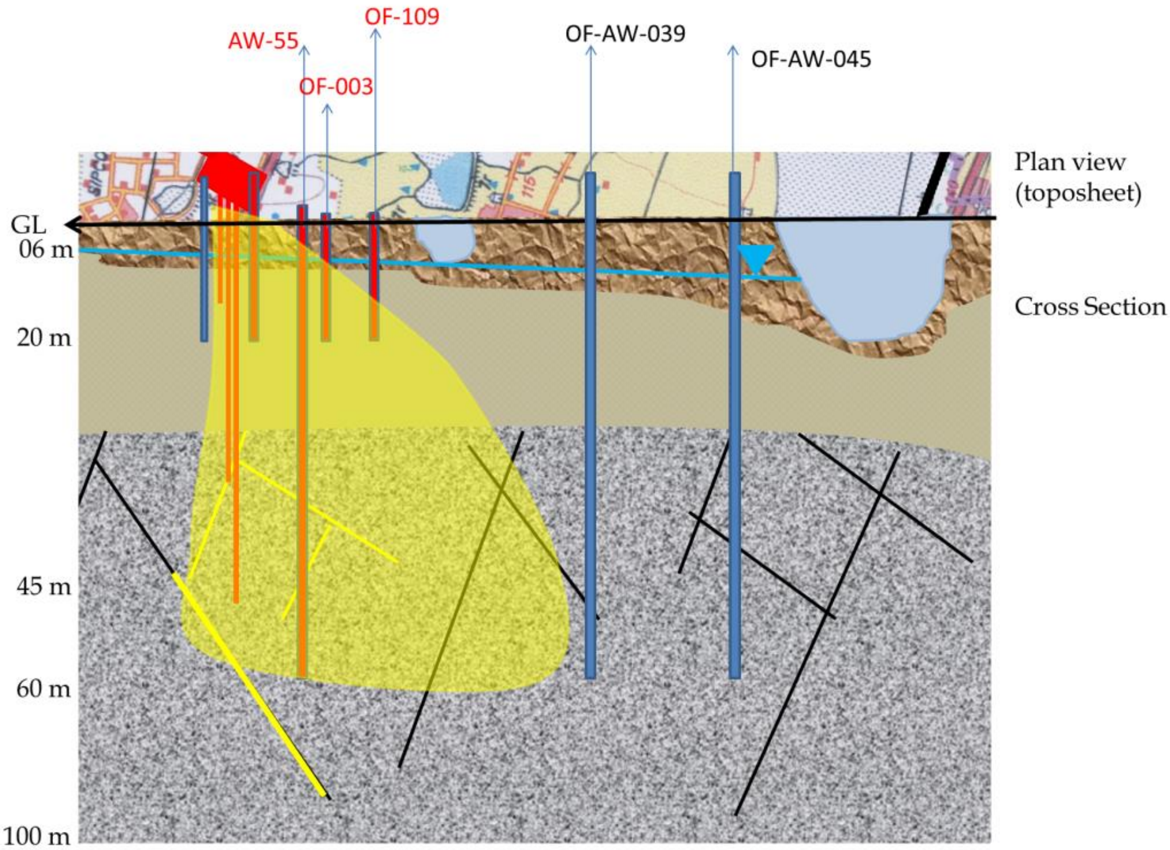
Table-11: Summary of Human Health SSTLs for Groundwater based on Hazard Index (HI), Non Cancer (all numbers are in mg/L)

Groundwater (mg/L)	Off-Site Residents (Child)	Off-Site Agricultural Worker/Fisherman (Adult)	On-Site Intrusive Maintenance Worker (Adult)
Chromium III	8.9	46.3	127
Chromium VI	0.0086	0.0411	0.687
Lead	0.034	0.162	3.35
Manganese	0.77	3.67	68.4
Zinc	0.48	2.30	44.9

3.3 Updated Conceptual Site Model (CSM)

The Preliminary Conceptual Site Model (CSM) developed during Staep-2 stage was been updated based on the subsequent field investigations and laboratory data. The updated CSM is given at figure-4.

Figure-4: Updated Conceptual Site Model: Cross Section



4. Remedial Approach and Design

The contaminated area in and around the premises of M/s TCCL, Ranipet, Tamil Nadu was inspected by Technical Expert Committee (hereinafter referred to as TEC) constituted by CPCB along with the representatives of CPCB, TNPCB and CPCB's Consultant on 03.03.2017. Subsequently, in the 9th meeting of the TEC organized at Ranipet, TN on the same day, had reviewed the technologies for remediation of TCCL contaminated area. Further, the TEC recommended technologies in its 13th meeting held on 02.07.2018 had been accepted by Project Steering Committee (PSC) under chairmanship of Chairman, CPCB.

4.1 Remedial Approach for Waste and Soil

Based on the multi-criteria evaluation of the shortlisted techniques proposed for Waste and Soil remediation, excavation with on-site treatment and backfilling on and on-site engineered secured landfill (SLF) has been found to be the most sustainable option. This approach is intended to reduce the concentration of chemical of concern (CoC) down to an acceptable level and eliminates further migration of Hexavalent Chromium from waste and/or soil into groundwater or surface water as applicable. This does not remediate the contaminants in the groundwater or surface water and therefore groundwater and surface impacts need to be addressed simultaneously.

Table-12: Summary of Remedial Technology for the Site

Matrix	Location	Selected Option
INTERIM		
Soil and Waste	On-site	Capping of existing waste dump with provision for storm water collection
FULL SCALE		
Waste and Soil	On-site	Excavation, Treatment, and Backfilling in on-site engineered secured landfill (SLF)
Groundwater	On-site and Off-site	Pump and Treat with Source Removal and Hydraulic Containment System

An interim remedial plan for limiting the surface run-off and limiting leaching of hexavalent chromium into groundwater is also presented in sections below. The interim plan consists of capping the existing waste on-site by grading and engineering a cap to limit any contamination from leaching into groundwater during monsoons. Along with the cap, a storm water drainage network is also proposed prevent any surface water run-off from the site.

a) Site Preparation

Prior to initiating remedial works, the site needs to be prepared for undertaking the remedial activities, these activities comprise of the following:

- Identification & Mapping of the various works areas: all the areas that require remediation activities need to be barricaded and marked for remediation;
- In case some of these areas are part of current operational activities, alternative areas, access points are to be created such that neither the operations not the remedial activities are obstructing each other. Provisions for water, wastewater (generated during remediation) to be identified and appropriate provisions to be made; and
- Areas to be marked for installation of remediation systems such as groundwater abstraction wells, groundwater treatment system, laboratory, offices, area for temporary stockpiling of contaminated material, treatment area for soil and waste, etc. to be identified.
- Demolition, decommissioning and decontamination of existing process equipment, buildings, and other structures on-site.

4.2 Full Scale Soil and Waste Remediation

Based on the evaluation of shortlisted techniques proposed for Soil and Waste, and the recommendations of TEC the techniques i.e. excavation, treatment and on-Site disposal in a secure landfill (SLF) was identified/selected to be the most sustainable option. This approach removes the chemicals of concern (Source removal) and eliminates further migration to soil and groundwater. This does not remediate the CoC in groundwater. Therefore, the impacts in soil and groundwater need to be addressed simultaneously.
This section presents the approach adopted for the areas where soil and waste was observed to be stored. Waste was observed to be stored in the northern portion of the Site while soil was found in the southern portion of the Site.

a) Excavation

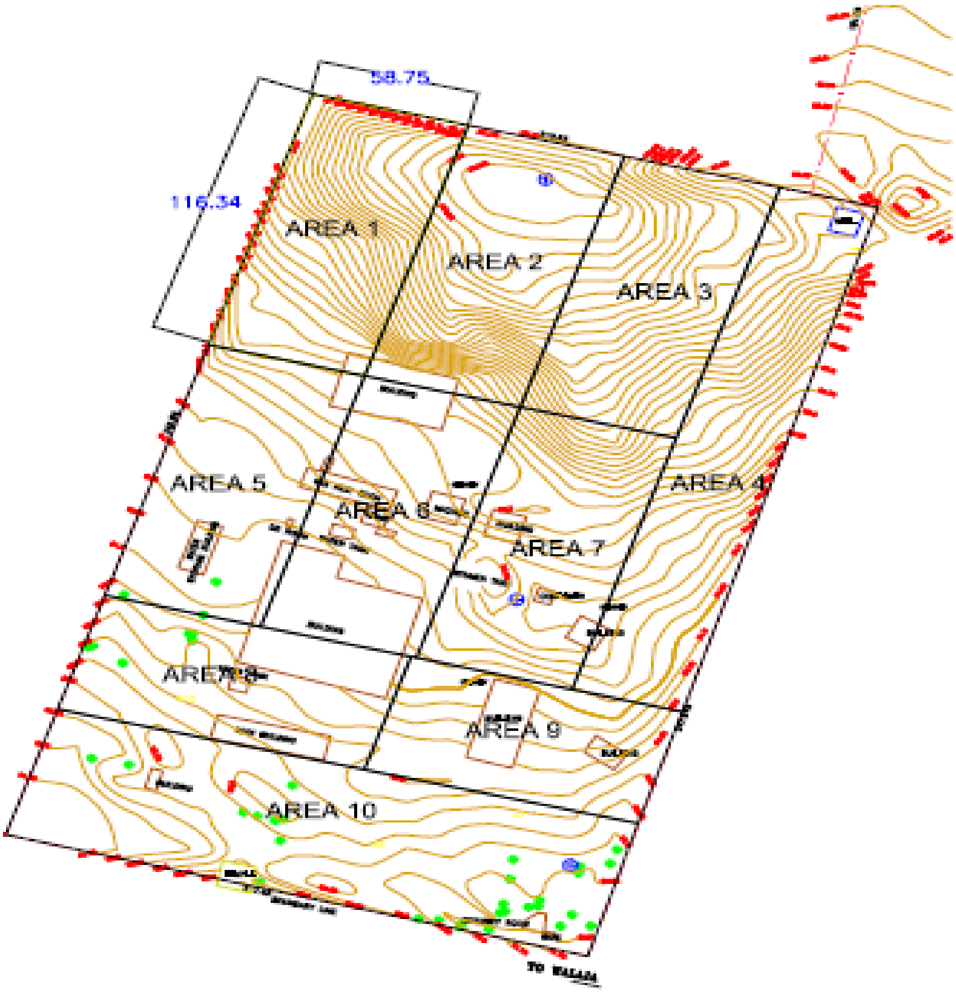
The management of soil and waste is proposed to be handled by excavation, treatment and on-site disposal in an on-site constructed SLF.

The soil and waste may be excavated, stored at a temporary location in the Site, treated and then stored in a constructed cell of a SLF in the Site.

(i) Excavation Plan

The excavation at the Site may be performed is a sequential manner. The site is divided in 10 separate areas and excavation will be performed simultaneously with soil and waste treatment and construction of SLF. The layout of the areas proposed for excavation are provided in figure-10 below:

Figure-5: Excavation Plan



(ii) Closure of Excavation Zones

The excavated areas within the site are anticipated to be used for construction of a secured landfill (SLF). Therefore, backfilling operations shall not be performed till SLF is ready. Construction of SLF and treatment have to performed simultaneously so that the treated soil and waste is backfilled without the need to excessive storage.

b) Soil and Waste Treatment

In order to eliminate the possibility of any further contamination of soil and groundwater it is proposed that the soil and waste mixture will be treated and stabilized prior to backfilling into a SLF. The following sections outline the process for treatment and stabilization of soil and waste.

The excavated soil and waste containing hexavalent chromium is to be treated by using Sodium Meta Bi-Sulphite (SMBS). The treatment process involves the following;

(i) Crushing and Grading

The excavated soil and waste will be transferred to crushing (jaw crusher etc.) using conventional earth moving equipment such as excavators, and dump trucks (tippers/dumpers). The crushed mixture will then be passed through grading (sieves etc) equipment to remove any large boulders or rocks.

The graded mixture will be passed onto the mixer where it will be dosed. The oversize material will be segregated and staged separately. The oversize material will be analyzed for hexavalent chromium exceedance with respect to SSTL. Depending up on the results the oversize material will either be used onsite for construction activities or can be disposed in the on-site landfill.

(ii) Mixing

The mixtures (undersize) will be passed on to a mixer (twin shaft or similar) where it will be dosed with acid, SMBS, lime and cement. The dosing requirements as per laboratory tests is provided below.

- SMBS = 11% w/w
- Acid = 20% w/w
- Lime = 25% w/w
- Cement = 10% w/w

Initially acid will be added to the mixture and once required pH has been achieved SMBS will be added. In order to get complete reaction water may need to be added as well. Once sufficient reaction time is achieved the treated mixture will be dosed with lime and cement to reduce the moisture content. The final dosing will vary at the site considering the variability of the hexavalent chromium concentration.

The mixer is proposed to be sized to handle approximately 335 m^3/day (500T/day). Additional capacity for mixer may be added to reduce the treatment time. The final design and sizing of the mixer will be determined by the subcontractor based on the estimated excavated volumes.

Multiple soil and waste samples will need to be collected for each batch during staging and treatment process for verification.

(iii) Dewatering

The mixture obtained post treatment may have a high moisture content. Although lime and cement are added to control the moisture, further moisture reduction may be required. Contractor shall evaluate the possible need and options.

(iv) Pre and Post Treatment Staging

The excavated soil and waste from the Areas mentioned above will be staged in an area of 1,000 m^2 each and approximately 3-5 such staging areas are to be provided, depending on space. The staging area shall be made with a 100 mm thick PCC Cover/Geotextile cover and the stockpile height of 2 m shall be maintained during staging of contaminated soil and waste.

Similarly, 4-6 post treatment staging areas are proposed with approximately 1,000 m^3 area each. The height of stockpile is assumed to be 3 m considering that the contamination has been treated. The staging areas shall be provided with properly sized leachate collection system which will discharge to the on-site treatment system.

Once dewatering is completed, the treated soil will be staged. Multiple samples will need to be collected and analyzed for hexavalent chromium as per CPCB guideline for verification. Only batched that clear the SSTL requirement shall be allowed to be backfilled into the SLF. Batches which fail will need to be treated again.

c) Secured Landfill

The secured landfill (SLF) is expected to occupy an area of approximately 27,194 m^2, a depth of 1 meter above the ground and rising to a height of less than 20 meters above the ground.

CPCB Guidelines on the design of a SLF for areas with shallow groundwater may be referred to for the design of the SLF. Broadly, the following are expected to be included in the design of the SLF:

- A double composite liner system at the bottom as the groundwater is shallow (4-5 mbgl);
- Leachate collection system including a trench;
- Top impermeable layer comprising HDPE liner and geomembrane;
- Clean top soil cover; and
- Concrete walls covered with geomembrane, not to exceed 20 meters in height, surrounding the secured landfill.

The closure period designates the time when the landfill is closed and capped as per the design. For this site, the closure period is expected to be 36 to 48 months.

The post-closure period designates the time of monitoring that must be performed after closure of the landfill. This phase typically extends for up to 30 years after closure, in compliance with orders specified by the CPCBs Criteria for Hazardous Waste Landfills (2001) and/or in the consent to operate when received from the State Pollution Control Board. For this site, a similar or longer period is likely to be required.

The volume of soil and waste has been estimated at 2,29,610 m^3 and post treatment the total volume is estimated to be 4,39,552 m^3. A 20% volume for margin is being considered, resulting in a total volume of 5,38,451 m^3 for landfill design purposes.

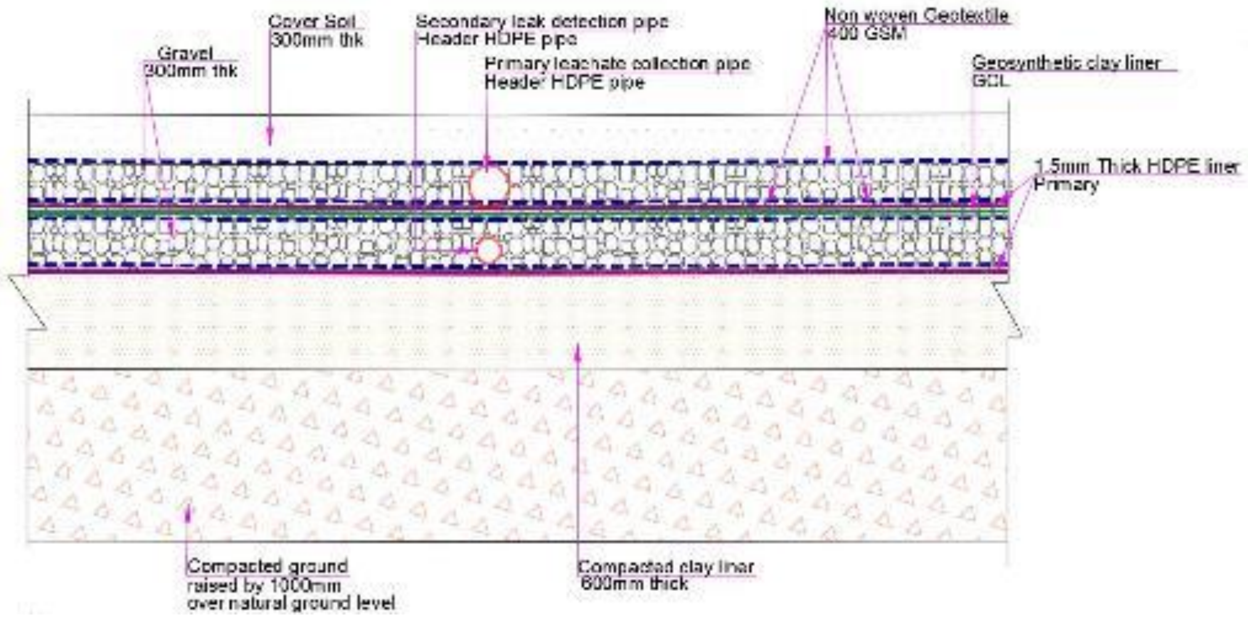
It is also understood that the waste is a one-time waste and would need to be capped in 24 - 48 month’s time period. This has a direct bearing on the leachate generation and the treatment.

(i) Landfill Section

To comply with the CPCBs Criteria for Hazardous Waste Landfills (2001), a double liner system with a primary leachate collection system and a secondary leakage detection system is required. The shape of the landfill should be adapted based on the existing conditions with a minimum of fills and cuts volume. In this case, as the landfill design has to be considered because of shallow groundwater levels.

The treated soil and waste should be levelled and compacted to achieve 90-95% maximum dry density as obtained from Proctor tests. The base area must have a sufficient slope to guarantee draining of leachate and storm water. The soil bearing capacity of the soil is an important criterion. The minimum soil bearing capacity (SBC) should be approximately 30 T/sqm after compaction. The typical cross section of the landfill to be employed for the site is given at Figure-6.

Figure-6: Typical Cross Section of Landfill



The layers within the liner section of the hazardous waste landfill, from bottom to top to be employed for the site, are as follows:

- Compacted ground should be elevated considering shallow groundwater levels.
- 600 mm thick compacted clay liner with Bentonite addition in case the soil is not having a permeability of 1 X 10-7 cm/s
- 1.5mm thick HDPE Liner
- 400 gsm Geotextile
- 300mm thick Gravel layer with HDPE pipe for secondary leachate collection
- 400 gsm Geotextile
- Geosynthetic Clay Liner (GCL)
- 1.5mm thick HDPE Liner
- 400 gsm Geotextile
- 300mm thick Gravel layer with HDPE pipe for primary leachate collection
- 400 gsm Geotextile
- Soil cover 300 mm thick

HDPE geomembrane with a standardized thickness less than 1.5 mm is not allowed. Only HDPE geomembranes should be used, which comply with the requirements of American Society for Testing and Materials (ASTM) or GRI GM 13 specifications.

d) Leachate Collection and Treatment System

(i) Estimation of Leachate

This is one of the important points that need to be considered during the preliminary design stage. It is important to ascertain the quantity of leachate that will be generated during the year and how the leachate will be collected and treated to discharge norms.

As it has been understood that the landfill will be filled and capped in a matter of 24-48 months, it should be remembered that the landfill should be constructed considering the monsoon period and provision should be made for temporary capping. This temporary capping will prevent any rainfall that enters the site from becoming leachate. Therefore, estimation of leachate includes only the water existing within the waste and soil.

Considering the average rainfall for the area, the leachate amount during rainfall event is estimated to be 44.54 m^3/day. However, as that these projections are based on assumed filling rates, assumed moisture content, and assumed leachate generation rates (per m^3 of waste deposited).

(ii) Leachate collection system

The main objective of the leachate collection system is to collect the leachate formed in the landfill in the shortest time period and bring it to a single point from where it can be pumped/ drained to the treatment plant. The leachate collection system will comprise of a drainage layer, perforated pipes, a collection sump and a pumping system to remove the same. This being a hazardous waste landfill, the regulations require a double liner system with primary leachate collection system and a secondary leakage detection system. The drainage layer will of 30 cm thick gravel layer with 2% or more slope having a permeability of 10-2 cm/sec.

(iii) Method of Treatment of Leachate

The leachate treatment will be treated on the on-site groundwater treatment system. Based on the site conditions a decision will have to be taken from the above alternatives. On-site treatment involves the complete treatment of the leachate to meet the discharge standards approved by the State Pollution Control Board.

e) Landfill Gas

Landfill gas is formed due to the degradation of the organic content in the landfill under anaerobic conditions. The quantum of gas is directly proportional to the organic content in the landfill. As there may be organic content remaining in the waste, passive venting system has to be adopted to release the gases. As such, minimum 12 passive gas venting wells are designed for removal of the landfill gas.

f) Covering of Waste and Intermediate Cover

Cover material includes imported cover such as soil or other inert material as well as material such as fine portion of construction and demolition (C&D) waste; any fractions of the C&D waste passing through the 1-5 mm sieve can be used as daily cover.

The cover soil should be pushed by a bulldozer or wheel loader up the slope and spread out as evenly as possible. The daily cover should be at least 10-15 cm thick. When constructing a body in an open area, the side slopes require soil cover also. When the capacity of the landfill is filled, the final closure should be directly carried out at site.

g) Final Cover/Closure

Once the waste is filled to the designed capacity in the landfill, the same has to be capped/closed to prevent any ingress of rainwater. As the rainfall is substantial in Ranipet, Tamil Nadu, it is essential to have a proper closure, which will prevent any ingress of water into the landfill.

To minimize infiltration of storm water in the landfill body and to allow storm water run-off, a surface sealing system has to be installed after the final completion of each landfill cell; this landfill is expected to be constructed and filled in a single cell. The main purposes of the final cover system are:

- To control the amount of storm water infiltration into the waste;
- To reduce leachate quantities;
- To prevent erosion;
- To minimise the migration of greenhouse gases into the atmosphere;
- To protect the base sealing (impermeable) layer;
- To minimise other emissions causing negative impacts on the environment like littering and odour.

The layers within the landfill cap section, from bottom to top, are as follows:

- Soil layer: The soil layer (300 mm) shall be of natural soil compacted properly
- Geosynthetic Clay Liner (GCL)
- 1.5 mm thick HDPE liner
- Geocomposite layer for draining of the rain water (i.e., geonet with geotextile on both sides)
- Vegetative soil layer of 450 mm thickness for the local grass to grow.
- Interceptor drains will be provided in the top soil layer for erosion control and proper cross drainage of the storm water; all cross drains empty into the gutter at the periphery of the cell.
- Toe drain/open gutter at the periphery of the cell closure to divert any rainwater, which falls on the cell. This surface water is not polluted/ contaminated and hence can be discharged into the nearby nala or storm drain or used for irrigation in the green belts.
- Passive gas wells will be provided at the sides and top of the closure, so that the gas, which is formed inside the closure, will be released naturally.

4.3.1 Schedule and Cost Estimate

The schedule of implementation of the selected remedial technology is subject to limiting field conditions. Assuming that the tasks are implemented without undue hindrance of any kind, the anticipated schedule is presented Table-13 below.

Table-13: Remedial Implementation Schedule - Waste

Activities	Sub-Activities	Anticipated Duration (months)*
Excavation of waste	Mobilization, Preparation of the land for staging area, access, excavation	24-48*

Activities	Sub-Activities	Anticipated Duration (months)*
	Loading of trucks, staging, characterization sampling	
	Chemical dosing, reduction and stabilization	
Secured Landfill	Disposal in the SLF	

**A range is provided considering that work may potentially be suspended during monsoons.*

(i) Assumptions

The cost associated with implementation of this remedial technology was estimated on the basis of the following design and market assumptions.

- The estimates on areas requiring remediation have been developed based on understanding of site specific geology and extent of impact exceeding the remedial goal;
- Based on Site Investigations, the nature of local soil is found to be sandy silt/silt. Based on literature review the density of such soils is found to be 1.34 tonnes/m^3. The same has been assumed for quantifications;
- The depth of contaminated soils that have been considered for quantity estimates have been detailed in Chapter 3 above;
- A stock pile area of 500 m^2, where excavated waste shall be temporarily stored shall be made with a 100 mm thick PCC Cover/Geotextile cover. A stockpile height of 2 m has been assumed for this evaluation;
- Typical work day is assumed to be **minimum** 8-10 hours;
- Considering delays during the excavation due to movement of the equipment and stockpiling, it is assumed that excavation will be performed at 1,000m^3/day. It is assumed that four (4) excavators will be able to excavate 1,000m^3 per day;
- It is assumed that three tipper trucks of 5m^3 capacities will transfer the waste to the staging area. A front end loader will be used at the staging area for loading and unloading including handling of stockpile;
- The rates for the excavator, tipper trucks and front end loader have been derived from Public Works Department (PWD) with a 20% buffer;
- Distance is assumed to be twenty (20) km, considering separate temporary locations where soil and waste is expected to be stored before and after treatment and during the construction of the secured landfill;
- The stabilization cost is basis internal and subcontracted studies conducted by Consultant. The total cost is expected to vary as dosing rate shall vary with each batch of waste processed for stabilization. The dosing rate assumed for estimation of cost purposes is:
  - 11% weight by weight (w/w) Sodium metabisulphite;

  - 25% w/w Lime;
  - 10% w/w Cement;
- The unit rates for chemicals were taken from whole sale dealers available on the internet;
- Survey of excavation progress to happen without undue hindrance of any kind. Survey will be conducted before the start of the excavation, when the final excavation depth is reached. This task also includes preparation of maps, as built drawings; and
- A 10% buffer is assumed for the cost estimation.
- Demolition of existing structure shall be conducted prior to start of excavation and landfill construction activities.

The cost for excavation treatment and disposal of soil and waste on an on-site SLF is estimated to be INR 194 Crore (excluding Project Management and Engineering costs). The cost indicated is an estimate for conditions as on dates of Step 5 studies and does not consider inflation or other changes in conditions.

4.3 Groundwater Remediation

Based on the evaluation of the shortlisted techniques proposed for groundwater remediation, the pumping and ex-situ treatment (P&T) in conjunction with the above remedies is the recommended sustainable option.

The proposed approach for treatment of contaminated groundwater at the Site comprises of installation of a hydraulic containment system (HCS) by the use of combination of:

- Groundwater containment wells, to prevent further migration of contaminated groundwater; and
- Groundwater source recovery wells, to expedite removal of contamination ‘hot spots’.

Principally, the HCS involves abstraction of sufficient quantity of water from abstraction wells along the down-gradient Site boundary to minimize or prevent further migration of impacted groundwater from this portion of the Site. The initial locations of the abstraction wells and optimum quantity of abstracted groundwater were evaluated using groundwater modelling. Based on the groundwater modelling scenarios, a hydraulic barrier can be created along the southern boundary of the Site. A total of fifteen (15) containment wells of which nine (9) operating wells shall be installed on the Site and five (5) wells off-Site. Based on the results of groundwater modelling, a total of 1,000 m^3/day of groundwater will need to be abstracted for achieving containment and mass removal at hot-spots of contamination.

The abstracted groundwater shall be collected at a central location and subjected to treatment by installation and commissioning of a Groundwater Treatment System (GTS), to remove the CoC (dissolved Cr (VI)), prior to discharge. For reporting, it is expected that the GTS shall be installed in a southern portion of the Site. The proposed location for this treatment unit is expected to occupy 50m x 50m. The location is subject to finalization after involvement of the relevant stakeholders.

4.5.1 Installation of Abstraction Wells

Based on groundwater analytical data and groundwater modelling scenarios, the required well depth to create a vertical capture zone is around 50 m below ground level (bgl). This includes installation of barrier wells along the southern and central section of the Site. A total of fifteen (15) containment wells need to be installed on the Site. The exact location of the wells will be evaluated based on the field conditions.

a) Well Installation Techniques

A 250 mm diameter borehole (~ 52m deep) will be drilled, for installation of the abstraction wells, using a Mud Rotary drilling method. After completion of drilling, 150mm diameter well screen and casing (uPVC) will be installed within the drilled bore. An approximately 1m thick layer of uniform filter pack will be placed at the bottom of the drilled boreholes as a well cushion. On top of this base layer, 42m length of screen, and slot size of 0.5-1 mm (3m sections) and about 3m length of casing will be installed (the casing will be encased in an appropriate and accessible well head structure).

The borehole annulus will be packed with a uniform filter pack containing well rounded gravels till 1m above the top of the screen. On top of this filter pack, top seal made of Portland cement/bentonite slurry will be installed. A sanitary/cover seal of Portland cement concrete will also be installed around the well. The seal will be contoured and graded to drain away from the well and to protect the well from direct surface water intrusion.

Following installation, the well will be developed by continuous flushing of the groundwater using air lift development techniques to develop the filter pack and to get good hydraulic continuity between the well and the aquifer.
As many associated connections, sample tapping points, valves (flow meters and flow regulators, etc.,) as possible will be housed inside the treatment unit and the number of connections installed over the constructed underground well head would be kept minimal.

b) Abstraction Pump Units and Risers

A multi-stage submersible pump will be installed within each abstraction well to pump and transfer water to the treatment system. Each pump will be suspended upon a rigid HDPE pipeline riser (about 38 to 50mm diameter). A suitable wellhead will be installed at each well location.

At each well head, fittings will be installed which will include flowmeter (electromagnetic flow tube type with rate and total flow display), pressure gauge, gate valve, and sample point tapping.

A level control system will be installed within each well to control the operation of the pump. This level control system will be adjustable from the wellhead, without the requirement for removal of the pump and riser installation. A non-return valve will be installed at the pump discharge.

c) Wellhead Control Systems

The abstraction system will operate on a continuous 24-hour basis. In the event of failure or abnormal operation of any component, the system will auto shutdown in a 'safe' mode and shall trigger an alarm for manual interference for restarting the system.

The operation of each individual abstraction pump will be controlled by conductivity level sensors installed within the wells. In the event of a low level (L) within the wells, the pumps will be automatically shut-down. The pump will automatically re-start when a high level (H) is reached. The pump will also shut-down in the event of motor overheat. Overload protection for each of the electrical motors shall be included.

A reliable three-phase power (415-440 V, 50 Hz) supply will be required at each wellhead location. Power supply isolators will be installed at the entry to each of the individual abstraction pumps.

The following external indications will be included on each of the individual abstraction pump wellheads:

- Power on/off;
- Pump on/off; and
- Visual alarm – low level within well.

The facility will be included to switch-off each of the abstraction pumps (on an individual basis) from the location of the main control panel. Overload protection for each of the electrical motors will be included. Power supply isolators will be installed at the entry to the main control panel and each of the individual abstraction pumps.

4.5.2 Groundwater Treatment Process

The treatment units anticipated to be installed along with the GTS include, at a minimum:

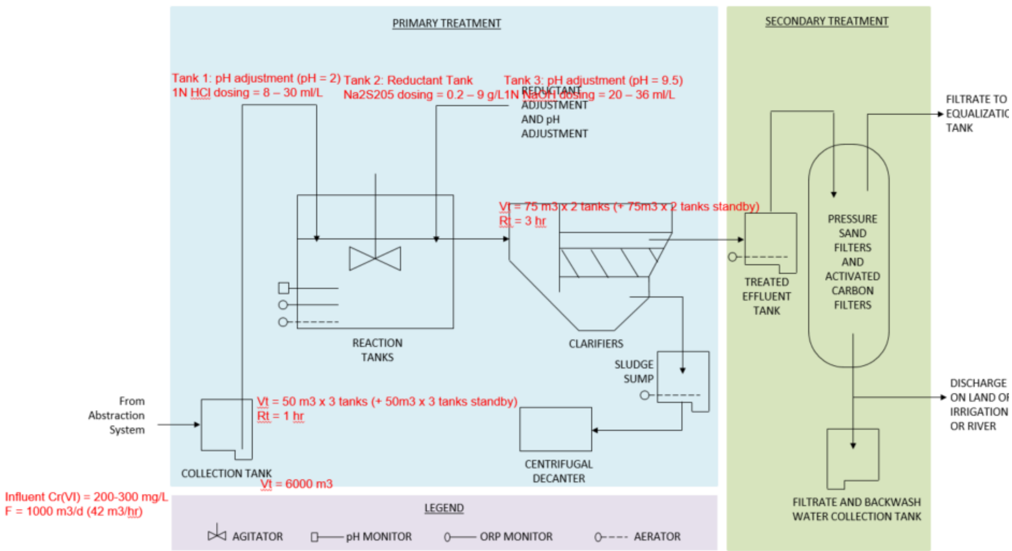
- *Collection Tank:* The groundwater from different abstraction wells shall be discharged into a Collection Tank;

- *Reaction Tank:* The collected groundwater shall then be conveyed to a Reaction Tank where it will be dosed with reductants including Sodium Meta-Bisulphite and Sulphuric Acid. Cr (VI) in the groundwater is expected to reduce to Cr (III), a less hazardous form and precipitate out of solution as sludge;
- *Clarifier:* The treated water shall be routed to a Clarifier where the sludge will be allowed to settle. The Clarifier shall be periodically emptied of the sludge at the bottom;
- *Filtration Units:* The overflow from the tank shall be routed through a Pressure Sand Filter (PSF) for further filtration, and subsequently through a series of Granular Activated Carbon (GAC) columns; and
- *Solids Handling Facilities:* The sludge from the Clarifier shall be conveyed to a Sludge Thickener to remove excess water, which shall then be routed to the equalisation tank. The final sludge shall then be disposed in a licensed HWMF.

The effluent water from this treatment system, once deemed compliant to the SSTLs, shall then be further treated to comply with the prevailing drinking water standards.

Please refer to Figure-7 for the Groundwater Treatment System Schematic.

Figure-7: Process Flow Schematic - Proposed GTS



a) Pre-Treatment

The purpose of pre-treatment is to generally eliminate constituents, which could interfere with or hamper the main treatment processes. Pre-Treatment consists of the following units:

- Collection Tank; and
- Aeration using atmospheric air.

Groundwater abstracted from the HCS wells gets pumped to a Collection Tank. In the tank, homogenization, and oxidation (by aeration) are done. Homogenization of the abstracted groundwater will help prevent shock loads on the system as concentrations after equalization are usually reduced and stable because of dilution and equalization. For the precipitation of iron and manganese (to a much lesser extent) present in groundwater, atmospheric oxygen is added to the water in order to raise the redox potential. Reduced compounds such as iron are then oxidized in the presence of oxygen. The compressed air is supplied by an air compressor and conveyed in to the water by several diffusors installed in the tank. The pre-treated water would then be conveyed to the next set of treatment unit(s).

b) Primary Treatment

The primary treatment system would primarily consist of the following units:

- Reaction Tank; and
- Clarifier.

The groundwater shall be conveyed to the Reaction Tank where it will be dosed with reductants including Sodium Meta-Bisulphite and Sulphuric Acid. Cr (VI) in the groundwater is expected to reduce to Cr (III), a less hazardous form and precipitate out of solution as sludge.

The sludge is separated out of solution in the Clarifier, where gravity settling is used to settle out the sludge and clear supernatant is carried over to the Clarified Water Tank and secondary treatment.

c) Secondary Treatment

The secondary treatment system would primarily consist of the following units:

- Clarified Water Collection Tank;
- Pressure Sand Filters;
- Granular Activated Carbon Filters; and
- Treated Water Collection Tank.

It is recommended to use Pressure Sand Filter and Granular Activated Carbon (GAC) Filters for the secondary treatment of groundwater. These units are proposed for the removal of any remaining Cr(VI) in the water.

From the Clarified Water Tank the water is pumped towards the sand filter. The sand filter is used to trap any remaining suspended particles in the water. The water enters the filter at the top end and flows through to the bottom of the filter.

Activated carbon is commonly used to adsorb natural organic compounds, taste and odor compounds, and synthetic chemicals in water treatment. Adsorption is both the physical and chemical process of accumulating a substance at the interface between liquid and solids phases. Activated carbon is an effective adsorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb.

Adsorption using activated carbon is particularly effective in treating low concentration waste streams and in meeting stringent treatment levels.

Primary factors in determining the required GAC volume for treatment are:

- Breakthrough time;
- Empty Bed Contact Time (EBCT); and
- Design flow rate.

The breakthrough time is the time when the concentration of a contaminant in the effluent of the GAC unit exceeds the treatment requirement. The EBCT is calculated as the empty bed volume divided by the flowrate through the carbon. The EBCT and the design flow rate define the amount of carbon to be contained in the adsorption units.

The backpressure on the filters is monitored to avoid clogging. Once the pressure has reached a predefined set point, the filters are backwashed.

The Ancillary Facilities anticipated to be installed along with the GTS include, but are not limited to:

- Blowers for Compressed Air;
- Transfer Pumps and conveyance piping;
- Backwash Unit; and
- Chemical Dosing Units.

d) Installation of GTS

The installation of the GTS, involves the following activities:

- Installation of conveyance piping from the abstraction wells to the equalisation tank at a flow rate of 1000 m^3/day (42 m^3/hr);
- Installation of an equalisation tank of capacity 6000 m^3;

- Installation of a total of six (6) tanks (capacity of 50 m^3 each) with three (3) operational and three (3) as standby. The three tanks would be sued for pH reduction by addition of acid, reduction chemical addition, and pH adjustment to neutral.
- Installation of two (2) Clarifiers (approx. 75 m^3 each for a retention time of 3 hours)
- Centrifugal decanter to dewater sludge from Clarifier
- Installation of a PSF (sized for 1000m^3/day);
- Installation of a GAC Column (sized for 1000m^3/day);
- Filtrate and backwash system
- Installation of treated water collection tanks;
- Conveyance piping for discharge of treated water;
- Periodic maintenance of the instrumentation and equipment may be required, and it may be done by backwashing the units using clean water;
- Onsite laboratory to analyze water and soil samples for verification

4.5.3 Implementation Schedule and Cost Estimates

The schedule of implementation of the selected remedial technology is subject to limiting field conditions. Assuming that the tasks are implemented without undue hindrance of any kind, the anticipated duration for each activity and the overall schedule for installation of the abstraction wells, and connection to the surface water treatment system are presented in Table-14*:*4 below for the schedule associated with installation of the water treatment system.

Table-14: Remedial Implementation Schedule – Groundwater

Anticipated Activity	**Sub-activities**	**Anticipated Duration (months)**
Installation of abstraction wells	Installation of abstraction wells	1
	Installation of conveyance piping	1
Installation of Treatment System	Procurement and Installation Instrumentation and Piping Testing and Commissioning	6-9
Operations	Long term monitoring of treatment system	15-20 years

A CAPEX is associated with drilling, installation of abstraction wells, and installation of the groundwater treatment system. The cost estimates are presented below, on the basis of the following design and market assumptions.

a) Assumptions

The following assumptions were taken in to consideration for making quantitative estimates for the surface water remediation system:

- The estimates on areas requiring remediation have been developed based on Consultant's understanding of Site specific geology and extents of contamination;
- The number of pumps, and abstraction rates were derived from modelling based on groundwater data from investigation, actual yield may vary;
- In total, the design consists of twenty (20) abstraction wells with pumps, pumping at 3-6m^3/hr. Of these fifteen (15) abstraction wells are located on-site and five (5) off-site.
- The estimated dosages are as follows;
    - 1N Hydrochloric Acid = 8 - 30 ml/L
    - SMBS = 0.2 - 9 ml/L
    - 1N NaOH = 20 – 36ml/L
- It was assumed that the pumping system shall operate for 24 hours a day;
- Empty Bed Contact Time (EBCT) of PSF was assumed to be 10 minutes, based on Standard Practices.
- EBCT of GAC Column was assumed to be 20 minutes; based on Standard Practices.
- Cost of analysis was included for thirty (30) samples per day, with twenty (20) from monitoring wells and ten (10) from treatment system.
- Monitoring is assumed to be conducted over fifteen (15) years, or compliance with the SSTLs, whichever happens earlier.

b) Estimated CAPEX

In total, the cost of installation of the abstraction system, and connecting it with the surface water treatment system is estimated to be INR 12 Crore.

c) Estimated OPEX

Assuming the life of the treatment system to be fifteen (15 years), the OPEX is estimated to be INR 1.29 crore per month.

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