

4.0 Strategy for Remediation of Contaminated Soil and Groundwater

4.1 Preamble:

The uncontrolled and unscientific disposal of liquid, solid, semi-solid wastes by UCIL during its operation from 1969 to 1984 has resulted in contamination of soil and groundwater as stated in previous chapter. Fortunately, the soil and ground water contamination is restricted to the UCIL premises and its immediate vicinity. The total quantum of contaminated soil was estimated at 11,00,000 MT. The total quantum of contaminated groundwater could not be estimated as explained in the previous chapter. The contaminated soil and groundwater needs to be remediated to a risk based levels. Considering the quantum of contamination and various site conditions Immediate and well as long term remedial measures have been identified and presented in the are following sections.

4.2 Immediate remedial measures:

- As discussed in Section 2.3, the boundary wall of the UCIL premises is broken at many places providing easy and uncontrolled access to nearby residents. Moreover, the SEP and the abandoned secured landfill area is also un-guarded and found to be damaged. BGTRRD is therefore advised to take immediate steps for ensuring proper fencing and security to these areas for preventing unauthorized access and use of these areas by public.
- It is recommended that as an immediate short-term measure, the five contaminated wells as specified in previous chapter should be immediately sealed so as to prevent use of water from these wells for any purpose by the residents.

- As mentioned in Section 2.3, excavation and recovery of dump material from the disposal areas by M/s Ramkey Ltd was incomplete as huge quantities of wastes (tarry wastes, off-specification products) still exist at various locations within UCIL premises. It is, therefore, recommended that these dumps should be carefully excavated and the excavated material should be properly collected, stored. The incinerable material, from such dumps shall be disposed off at an authorized TSDF at Pithampur in Madhya Pradesh, in accordance with the prevailing hazardous waste management rules and regulations. The non-incinerable wastes being larger in quantity shall be disposed off at an on-site secured landfill facility as per the plan delineated under long-term measure.
- It was also observed during the reconnaissance survey that various plants, buildings, sheds and equipments located within UCIL premises are in dilapidated conditions and appeared to be contaminated. It is recommended that decontamination and decommissioning of these items should be taken by BGTRRD on priority, as per the plan delineated by IICT, Hyderabad. **These activities must be completed prior to the commencement of full scale soil and groundwater remediation as these activities may further result in contamination of soil and groundwater.** As informed by IICT, about 300 MT of waste is likely to be generated during decontamination and decommissioning activities. These wastes shall also be disposed off at an on-site secured landfill facility as per the plan delineated under long-term measure.

4.3 Long-term remedial measures

Remediation of contaminated soil and groundwater may be taken-up by BGTRRD as a long-term measure. The main objective of the long-term measure is to remediate the contaminated land and groundwater below the risk based clean-up levels. A range of technologies is available for remediation of pesticide and heavy metal contaminated soil and Groundwater

to the risk based remediation/clean-up level. General approaches to remediation of contaminated soils include isolation, immobilization, toxicity reduction, physical separation and extraction. One or more of these approaches are often combined for more cost-effective treatment. A number of the available technologies have been demonstrated in full-scale applications and are presently commercially available. These include both in-situ (in place) and ex-situ remediation technologies such as thermal desorption, soil vapor extraction, air sparging, bioventing, permeable reactive barriers, natural attenuation, bioremediation, chemical oxidation, thermal technologies, secured landfilling and pump and treat system. These technologies were assessed vis-à-vis site-specific condition (extent of contamination, quantum of soil, nature of soil and availability of off-site facilities and cost). The risk based remediation levels and details of technologies considered for the study are presented in the following section.

4.3.1 Risk based remediation levels

Since clean-up standards for hazardous waste contaminated sites are yet to be developed and notified by the regulatory agencies in India, the latest (2009) standards/screening levels published by USEPA (*“Regional Screening Level (RSL) Summary Table”, USEPA, December 2009*) have been considered for the present study. The USEPA has published two sets of screening levels depending upon the landuse category (industrial, residential) and the objective (groundwater protection) of the remediation. Considering the possible use of groundwater in the area for drinking and also considering the possibility of contamination of groundwater in future due any natural calamities, the soil remediation standards for protection of groundwater have been considered for the present study. The standards for the contaminants identified for the present study are listed in **Table 38**.

**Table 38: Screening standards for assessing the contamination levels
(Compounds relevant to the studies)**

S.No.	Name of the compound	Screening Standards (USEPA- DEC.2009)	
		Industrial Soil (mg/kg)	Ground water protection (mg/kg)
1	Carbaryl	62000	3.3
2	Aldicarb	620	0.09
3	Alpha Naphthol(nearest is Naphtha)	31000	NA
4	Alpha HCH	0.27	0.000062
5	Beta HCH	0.96	0.00022
6	Gama HCH(Lindane)	2.1	0.00036
7	Technical HCH	0.96	0.00022
8	Chloroform	1.5	0.000053
9	Toluene	45000	1.6
10	Chlorotoluene	20000	0.71
11	Dichloro benzene	9800	0.36
12	Trichloro benzene	4900	0.087
13	Elemental mercury	34	0.03

For remediation of contaminated groundwater, the clean-up level is considered as the background concentration of these contaminants in surroundings groundwater and soil which is practically zero in this case.

4.3.2 Remediation of contaminated soil

As estimated in previous Chapter, approximately 11,00,000 MT of soil is contaminated within and outside UCIL premises. In addition, non-incinerable wastes excavated from the dumpsites and wastes generated during decontamination and decommissioning of plant and machinery are also required to be disposed off. Due to the clayey nature of the contaminated soil, and persistent nature of contaminants in-situ technologies such as thermal desorption, permeable reactive barriers, bioremediation etc. may not be feasible in the present case. Therefore an ex-situ treatment and disposal is recommended.

Further, the excavation and transportation of such a huge quantum of soil to the Pithampur TSDF facility , which is located at about 150 km from UCIL, Bhopal, would require tremendous man and machine resources. Moreover, TSDF may not be designed to handle, treat and dispose off this additional load of contaminated soil. Hence an onsite disposal is recommended. **Thus an ex-situ on-site remediation is recommended for implementation.**

The most feasible ex-situ on-site remediation system would be the establishment of a secured landfill system within the premises of UCIL. Under this option, the soil from the contaminated area needs be excavated, treated (if necessary) and disposed off in the secure landfill facility. The landfill shall comprise of layers of clay and flexible membrane liners, leachate collection and removal systems, landfill cover system (clay, flexible membrane liners, and vegetative cover), landfill gas collection system, leachate and landfill gas treatment system. The construction, operation and monitoring of onsite secured landfill should be as per the prevailing guidelines specified by CPCB.

Since the major waste disposal in the past has taken place in disposal area II, it is recommended to establish the TSDF in this area. This would minimize the backfilling of excavated areas by fresh soil. The requirement of fresh soil for backfilling of excavated areas may further be minimized by used of uncontaminated construction debris.

Cost estimates for establishment of onsite secured landfill:

Based on the data/information collected from various secured landfill contractors, the cost of construction of secured landfill facility varies from Rs. 600 to 900 per m³ of waste volume. Considering a total volume of contaminated soil of about 6,50,000 m³ and nearly 6,50,000 m³ for binders (1:1 ratio) for solidification/stabilization, the total quantum of treated soil becomes 13,00,000 m³. Thus, the cost of construction of secured landfill will be in the range of Rs 78 crore to 117 crore (average Rs. 100 crore). This cost

is subject to 20 % variation depending on the pretreatment needs which can only be determined at the time of disposal. This cost estimates are based on the prevailing rates may vary from contractor to contractor.

4.3.2 Remediation of contaminated groundwater

Based on the detailed literature review on remediation of pesticide contaminated sites, a pump and treat system is recommended for remediation of contaminated groundwater at UCIL.

The pump and treat system would comprise of pump, storage tanks, sand filter and activated carbon filter. The size and capacity of these units will depend on the borewell discharge. Considering the security issues outside the UCIL premises it is recommended to install the pump and treat system with in the UCIL premises. In this case contaminated water from the five borewells should be transported to the treatment system by any suitable means. The exhausted activated carbon from this treatment unit should be disposed off through incineration at an authorized TSDF as per prevailing hazardous waste management rules and regulations. Since the quantum of contaminated groundwater is not known, these units should be operated till the background concentration of the contaminants are achieved.

Cost estimates for remediation of contaminated groundwater:

The capital cost for such pump and treat unit shall be in the range of 25 to 30 lakhs. The operating and maintenance cost of such unit is in the rage of Rs. 10 to 15 lakhs per annum including cost of activated carbon and its disposal.

It is recommended that, BGTRRD should engage competent professional contractors for detailed engineering, and execution of these options.

5.0 Conclusions and Recommendations

- M/s. Union Carbide India Ltd. (UCIL), manufactured carbamate pesticides and the associated intermediate chemicals at their Bhopal unit from 1969 to 1984. The unit was closed down in December 1984 as a result of the infamous accident of leakage of methyl iso-cyanate gas (MIC).
- The solid, semi-solid, liquid and tarry wastes generated during the manufacture of pesticides and associated chemicals were dumped by UCIL within their premises from 1969 to 1984.
- The unscientific disposal of these wastes could have resulted in contamination of land and water environment in and around plant premises of UCIL and may require remediation, in case the contamination levels exceed the permissible limits delineated by national/international regulations.
- The contamination of soil and groundwater in and around UCIL premises is solely due to dumping of various wastes during 1969 to 1984, and MIC gas tragedy has no relevance to it.
- Based on the directives of the Task Force constituted by Hon'ble High Court of Madhya Pradesh, the BGTRRD sponsored a joint study to NEERI and NGRI in March 2009 for assessment of contamination and delineation of suitable strategies for the remediation of contaminated areas.
- Considering the background data/information generated by the past studies carried out by NEERI, and apprehensions/issues raised by various agencies/organizations, the field studies were carried out by NEERI and NGRI during April 2009 and May 2010 which involved reconnaissance

survey, geophysical and hydrogeological investigations, sampling and analysis of soil and groundwater in and around the UCIL.

- During the reconnaissance survey, NGRI-NEERI team observed remains of various manufacturing plants, machinery, buildings and sheds within UCIL premises. Most of these structures were in dilapidated conditions and appeared to be contaminated.
- As per the terms of reference (TOR) for the present study, the decontamination and safe disposal of plant, machinery, buildings and materials from the abandoned manufacturing units as well as clearing of dense bushes from the UCIL premises were to be completed by BGTRRD prior to the initiation of study by NGRI and NEERI. However, these tasks were not completed prior to the commencement of field studies. Therefore, the areas, which were not clear of structure and bushes, could not be included by NGRI-NEERI in the present study.
- The reconnaissance survey of the open areas within plant premises revealed existence of a number of dumps especially in disposal area I and disposal area II. The existence of dumps within UCIL premises indicated that the excavation and recovery of wastes from the dumpsites by MPPCB through M/s Ramkey Ltd. is still incomplete.
- During the reconnaissance survey it was also observed that the boundary wall of the UCIL premises is broken at many places which provided an easy access to the people living around the premises. The site was used by children as a play ground.
- The reconnaissance survey of the SEP area outside the UCIL premises revealed existence of one SEP and an abandoned landfill which were found to be damaged.

- The field studies for assessment of contamination comprised of detailed hydrogeological investigations (geophysical investigations, borehole drilling, development of monitoring wells etc.), followed by collection and analysis of existing field samples (dumpsite, subsurface soil and groundwater). The hydrogeological investigations were carried out by NGRI whereas sampling and characterization of soil and groundwater were carried out by NEERI.
- The geophysical investigations carried out by NGRI indicated possibility of contamination at three sites (Site I, Site III and Site V) out of nine sites. The depth of contamination at these sites was limited to about 2 m, except at one dump (Site III) that could be deeper (4-8m). These dumps were isolated from each other.
- The hydrogeological studies carried out by NGRI revealed that entire area of UCIL premises is occupied by a thick layer of black silty clay and yellow silty clay up to a depth of about 22 to 25 m below ground level. The groundwater occurs in sandy alluvium with pebbles at a depth of around 25 m below ground surface under confined condition. The groundwater flow direction, in and around the UCIL premises, was in south-east direction which could change with time. It was also reported by NGRI that there existed a subsurface elevation or mound near the central part of the UCIL premises, which diverted the subsurface water flow in north-east or south-east directions depending on the approach of the flow.
- In order to assess vertical as well as lateral extent of contamination, soil and groundwater samples were collected by NEERI from various locations in and around UCIL premises. Three rounds of sampling were undertaken. The standard international sampling and analysis protocols as delineated in the report, were followed during the monitoring of soil and groundwater.

- Based on the review of the past process operations as well as apprehensions raised by various agencies/organization the relevant parameters were selected for monitoring. These include semi volatiles/pesticides (Carbaryl, aldicarb, α -naphthol, hexachlorocyclohexane isomers and naphthalene), volatile organics (carbon tetrachloride, chloroform, methylene chloride, 1,2-dichlorobenzene, chlorotoluene and toluene), and heavy metals (mercury, cadmium, nickel, chromium, cobalt, lead, zinc, and copper).
- Monitoring of soil quality in the upstream of UCIL premises (control samples) revealed that none of the volatiles and semi-volatile compounds are present in the soil.
- Analysis of subsurface soil (collected during drilling of 5 borewells) indicated contamination of soil up to a depth of about 2 m. Major contaminants detected at the site include: HCH isomers, aldicarb, carbaryl, α -naphthol and mercury.
- The analysis of soil collected from possible dump areas (other than drilling areas) also indicated contamination of soil in terms of above mentioned contaminants.
- The soil in and around SEP area located outside UCIL premises was also found to be contaminated in terms of some of these contaminants.
- The concentrations of other physico-chemical parameters in soil samples collected from UCIL premises and SEP area are similar to upstream soil samples.
- The comparison of analytical results of upstream and soil samples collected from UCIL premises and SEP area clearly indicate that soil in these areas is contaminated with aldicarb, carbaryl, α -naphthol, three HCH isomers, dichlorobenzene and mercury as none of these compounds are present in the upstream soil samples collected outside the UCIL plant.

- The total volume of contaminated soil (within and outside UCIL premises) is estimated to be 6,50,000 m³. Assuming a bulk density of 1.7 gm/cc of soil, the total quantum of contaminated soil requiring remediation amounts to 11,00,000 MT.
- The monitoring of groundwater samples collected from the borewells constructed by NGRI and one existing borewell near the main entrance of UCIL indicated that none of the volatiles and semi-volatiles are present in these samples. This clearly indicates that the contaminants within UCIL plant have not percolated through the clayey soil strata (22 to 25 m thick) and have not reached the groundwater. The repeat sampling of these borewells could not be carried out by NEERI since these borewell were found to be broken, tampered and filled with unknown materials.
- Monitoring of groundwater collected around UCIL premises indicated isolated contamination of 5 wells in the vicinity of UCIL premises. Since, some of the wells are in the upstream of groundwater flow direction the possibility of contamination, due to seepage of contaminants through subsurface strata to the aquifer is ruled out. Few of these groundwater sampling locations are situated very close to UCIL premises as well as nearer to the solar evaporation ponds and abandoned landfill. The possibility of contamination of these wells may be attributed to surface runoff from the UCIL dumps and improper management of SEP and landfill. Remaining groundwater samples did not show any contamination with respect to UCIL derived contaminants.
- Considering the extent of contamination and various site conditions, immediate and well as long-term remedial measures were recommended.

- Under immediate measures following recommendations were made:
 - Proper fencing and security to UCIL premises and SEP area for preventing unauthorized access and use of these areas by public.
 - Immediate sealing of five contaminated wells so as to prevent use of water from these wells for any purpose by the residents.
 - Excavation and recovery of dumps materials. The incinerable wastes should be disposed off in TSDF at Pithanpur. The non-incinerable wastes to be disposed off in on-site secured landfill facility.
 - Decontamination and decommissioning of plant, machineries and buildings prior to remediation of contaminated soil and groundwater

- Under long-term measures remediation of contaminated soil and groundwater was recommended. For remediation of contaminated soil, an on-site secured landfill facility was recommended. For contaminated groundwater, pump-and-treat system was recommended.

- The cost of soil remediation through secured landfill is estimated to be in the range of Rs 78 crore to 117 crore. The capital cost for such pump and treat unit shall be in the range of 25 to 30 lakhs. The operating and maintenance cost of such unit is in the range of Rs. 10 to 15 lakhs per annum including cost of activated carbon and its disposal.

- It is recommended that, BGTRRD should engage competent professional contractors for detailed engineering, and execution of various remedial measures suggested by NEERI.