ACTION PLAN ENVIRONMENTAL REMEDIATION IN AND AROUND UCIL, BHOPAL

EXPERT ROUNDTABLE, APRIL 25-26, 2013

CENTRE FOR SCIENCE AND ENVIRONMENT

CSE

The Centre for Science and Environment (CSE) is a public interest research and advocacy organisation based in New Delhi. The Centre researches into, lobbies for and communicates the urgency of development that is both sustainable and equitable.

The scenario today demands using knowledge to bring about change. In other words, working India's democracy. This is what we aim to do.

The challenge, we see, is two-pronged. On one hand, millions live within a biomass-based subsistence economy, existing at the margins of survival; the environment is their only natural asset. But a degraded environment means stress on land, water and forest resources for survival. It means increasing destitution and poverty. The opportunity to bring about change is enormous. But it will need a commitment to reform – structural reform – in the way we do business with local communities.

On the other hand, rapid industrialisation is throwing up new problems: growing toxification and a costly disease burden. The answers will be in reinventing the growth model of the Western world so that we can leapfrog technology choices and find new ways of building wealth, which will not cost us the earth. This is the challenge of the balance.

Our aim is to raise these concerns and to participate in seeking answers and more importantly, in pushing for the answers to become policy and then practice. We do this through our research and by communicating our understanding through our publications. We call this knowledge-based activism.

We hope we will make a difference.

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Content









Foreword

DURING 1969-84, Union Carbide India Limited (UCIL) mainly produced three pesticides namely sevin (carbaryl), temik (aldicarb) and sevidol, which is a formulation of carbaryl and gamma-hexachlorocyclohexane (γ-HCH). All these years, the toxic wastes and products were being dumped at certain area inside the plant and outside in the solar evaporation pond (SEP). The UCIL plant was shut down after the gas leakage disaster in 1984 and the highly toxic waste dumped has been lying in the plant premises and SEP ever since. Over the years, this waste has been a continuous source of soil and groundwater contamination and therefore a cause of serious public health concern for residents in the surrounding areas.

There have been several studies to assess the level of contamination and outline the fate of the UCIL site. Governments at the state and center along with judiciary at the highest level are involved to address this issue of contamination and remediation. However, the situation at the ground has not changed to the satisfaction of the local people and the scientific community at large.

Centre for Science and Environment (CSE) analysed about 15 studies conducted over the last twenty years to assess soil and groundwater contamination in and around the UCIL site. These studies were conducted by several non-government organisations, Madhya Pradesh state agencies, Central Pollution Control Board (CPCB), Council of Scientific & Industrial Research (CSIR) institutes such as National Environmental Engineering Research Institute (NEERI), National Geophysical Research Institute (NGRI), Indian Institute of Chemical Technology (IICT) and Indian Institute of Toxicology Research (IITR).

Most of these studies confirm contamination and have more convergence than divergence. The nature of contaminants found in the soil and the place from where they were found are similar in several studies. Contamination of groundwater has also been reported in most studies. Characterisation of toxic waste lying at the UCIL site and dumped at SEP is done by few.

CSE after analysing these previously conducted studies together with recent developments and success (or lack of it) in disposal and remediation, realised the need for a discussion to develop a consensus on the future course of action among all stakeholders, such as those who have studied and suggested remediation measures, those who would regulate, monitor and execute the suggested plans, scientific community and affected local community from Bhopal.

A two-day roundtable meeting was organised on April 25-26 at New Delhi that focused on developing a road map on remediation of soil and groundwater contamination, disposal of toxic chemical waste, remediation of plant machinery and the fate of the site. For the first time, such a discussion was held, wherein active participation was observed among experts from concerned CSIR institutes such as NEERI, IICT, IITR that have comprehensively studied and reported on this in the past, CPCB – which is actively involved at present, several IITs, hazardous waste management companies, and affected community from Bhopal.

The expert group extensively deliberated on several aspects including the current state of contamination, immediate and long-term measures to prevent further spread of contamination, gaps in previous studies and suitability of various remediation technology options.

Collective understanding in the group reflected agreement on the presence of contamination in soil, need of further studies to assess the nature and extent of groundwater contamination, lack of understanding on the waste that is dumped at SEP, high possibility of more waste dumps within the site thereby much higher amount of toxic waste than the currently discussed 350 tonnes, preservation of the site as a memorial and the need for breaking the institutional logjam that has held up the remediation and clean-up operations.

Towards the end of deliberations, the expert group collectively developed an action plan on way ahead such as on how the toxic waste should be disposed, what needs to be done with the contaminated soil and groundwater, how to prevent further contamination and what should be the fate of the UCIL site.

We at CSE hope that this report helps in better understanding of the situation and is successful in initiating a swift and concrete action to address this important issue of public health for the people of Bhopal.

Expert participants in the roundtable: April 25-26, 2013

Name	Designation	Organisation
A Krishna Reddy	Retd. Scientist ‘F’	Indian Institute of Chemical Technology, Hyderabad
Abdul Jabbar	Convenor	Bhopal Gas Peedit Mahila Udyog Sangathan
Amit Khurana	Programme Manager	Centre for Science and Environment
Avimuktesh Bhardwaj	Research Associate	Centre for Science and Environment
B Binod Babu	Scientist 'D' & Incharge, Hazardous Waste Management Division	Central Pollution Control Board
Balkrishna Namdeo	President	Bhopal Gas Peedit Nirashrit Pension Bhogi Sangharsh Morcha
Chandra Bhushan	Deputy Director General	Centre for Science and Environment
D B Boralkar	Environmental Management Counsel	Freelance Consultant
D C Singhal	Retd. Professor & Head, Department of Hydrology	Indian Institute of Technology, Roorkee
D D Basu	Advisor	Centre for Science and Environment
Ganesh Sivaramakrishnan	Business Development, IWM Division	Ramky Enviro Engineers Limited
H S Simha	Principal Scientist, Design Engineering	Indian Institute of Chemical Technology, Hyderabad
Indumathi M Nambi	Assistant Professor, Department of Civil Engineering	Indian Institute of Technology, Madras
J K Bassin	Scientist ‘F’ and Head	National Environmental Engineering Research Institute, Delhi
J S Kamyotra	Member Secretary	Central Pollution Control Board
Juergen Porst	Director	DR PORST INTERNATIONAL
Masood Mallick	Managing Director	Environmental Resources Management (India)
N D Jayaprakash	Coordinator	Bhopal Gas Peedit Sangharsh Sahyog Samiti
Nawab Khan	President	Bhopal Gas Peedit Mahila Purush Sangharsh Morcha
Pinaki Sar	Associate Professor, Department of Biotechnology	Indian Institute of Technology, Kharagpur
R C Murthy	Scientist 'F' & Head, Analytical Chemistry Section	Indian Institute of Toxicology Research, Lucknow
Rachna Dhingra	Member	Bhopal Group for Information and Action
Ram N Agnihotri	Vice President & National Head, Hazardous Waste Operations	Ramky Enviro Engineers Limited
Rashida Bee	President	Bhopal Gas Peedit Mahila Stationery Karmchari Sangh
Satinath Sarangi	Member	Bhopal Group for Information and Action
Sunita Narain	Director General	Centre for Science and Environment
Swaranjit Singh Cameotra	Sr. Principal Scientist & Deputy Director	Institute of Microbial Technology, Chandigarh
T I Eldho	Professor, Department of Civil Engineering	Indian Institute of Technology, Bombay
T R Chauhan	Former Plant Operator	Union Carbide India Limited
Tapan Chakrabarti	Emeritus Scientist, CSIR & Former Director	National Environmental Engineering Research Institute, Nagpur

1 SUMMARY OF STUDIES CONDUCTED SO FAR

About 15 studies have been conducted to assess contamination in and around the UCIL site. All these studies have been conducted over two decades by concerned government agencies and certain non-government organisations.

Organisations that have studied this contamination issue include:

- CSIR institutes such as NEERI, NGRI, IICT, IITR
- Central and state agencies such as CPCB, Madhya Pradesh Pollution Control Board and Public Health Engineering Department of Madhya Pradesh
- Non-government organisations such as Greenpeace International, CSE, Fact Finding Mission and People's Science Institute

The complete list of studies is mentioned in Annexure 1.

The focus of studies has been soil and groundwater contamination. SEP area and the toxic waste stored at the site is studied by few. Certain studies have recommended plans for remediation of soil and groundwater and decontamination of existing machinery and structure at the site.

Analysis of study findings reflects contrary viewpoint on few aspects only. For instance, there is a consensus over presence of contamination in soil at the site. More importantly, a wide range of studies found similar set of contaminants in the soil samples and linked the contamination with the process chemicals and waste generated by UCIL (see Box: *UCIL – Production process and chemicals*) However, the nature and extent of groundwater contamination in surrounding areas was found to be varying across studies. This could be due to temporal and seasonal difference in sample collection.

Contaminants found by most studies in soil and groundwater in and around UCIL site can be traced back to the production process at UCIL

UCIL – Production process and chemicals

UCIL used to manufacture three different kinds of pesticides: Carbaryl (trade name sevin), aldicarb (trade name temik), and a formulation of carbaryl and gamma-hexachlorocyclohexane (γ-HCH) sold under the trade name sevidol. Carbaryl and aldicarb fall under carbamate group of insecticides.

For manufacturing sevidol, γ-HCH was extracted from the technical grade HCH, which is a mix of several isomers of HCH (mainly α, β, γ and δ–HCH). UCIL used to buy technical grade HCH, extract γ-HCH and throw the remaining isomers as waste within the factory and outside in the waste dump site (also called by UCIL as solar evaporation pond). HCH and its isomers are highly persistent and toxic organochlorine pesticides.

Hexachlorobenzene (HCB) is an impurity in the technical grade HCH and was also produced as a byproduct of various chemical processes in the UCIL factory. Chlorinated benzene compounds were either used by UCIL as solvents or are degradation products of HCH or HCB. For instance, 1,2 dichlorobenzene or ortho-dichlorobenzene was used as solvent for producing alpha-naphthol – a chemical used in the production of sevin, the main product of UCIL. Chlorinated benzene compounds are used as insecticides and fungicides.

Mercury was used as a sealant in the sevin plant and chromium was used as a coolant in the cooling plant at the UCIL.

CHANDRA BHUSHAN / CSE

Plant structure at UCIL, 2009

Overall, this convergence in findings of soil contamination and variation in groundwater is well illustrated by select studies done in the recent past. NEERI and NGRI in 2009-10, assessed contamination in and around UCIL and suggested measures for remediation. Similarly in 2009, CSE, a non-government organisation, along with CPCB, collectively conducted studies on soil and groundwater contamination in and around UCIL (see Box: *NEERI-NGRI, 2010; CSE AND CPCB, 2009*).

NEERI-NGRI, 2010

Bhopal Gas Tragedy Relief and Rehabilitation Department, Government of Madhya Pradesh granted this joint study to NEERI-NGRI to assess contamination and delineate suitable remediation strategies in and around UCIL site. It involved a reconnaissance survey of the UCIL site, geophysical and hydrogeological investigation, sampling and analysis of soil and groundwater in and around the UCIL.

The survey found broken boundary walls at many places and dilapidated plant, machineries and buildings. Several dumps were present. SEP and an abandoned landfill was found damaged. The study also noted that the excavation of dumps done earlier by M/s. Ramky Limited was incomplete. Three out of the nine suspected dump sites were assessed for contamination.

The depth of soil contamination was estimated to be upto two metres at most places. Key contaminants found in the soil include cabaryl, aldicarb, HCH isomers and alpha naphthol and heavy metals such as mercury, lead and chromium. Apart from isolated contamination in five wells in the downstream area outside the UCIL, no contaminants were found in the groundwater. Presence of the contaminants was attributed to surface runoff from the dumps. Presence of very low permeability due to black and yellow silty clay in the locality was quoted as a reason for absence of ground water contamination caused by seepage.

Suggested long-term remedial measures include on-site secured landfill of about 1.1 million tonnes of soil and remediation of groundwater by 'pump and treat' method. Certain immediate measures include securing the site and SEP; decontaminating and decommissioning of plant, machinery and structure before remediation; excavation and recovery of dumps and incineration of the incinerable; sealing of the five contaminated wells.

CSE AND CPCB, 2009

In a joint study, conducted in Oct 2009, Centre for Science and Environment, a Delhi based non-government organisation, alongwith CPCB, tested soil and groundwater samples from in and around UCIL site. Soil samples were collected together by both the institutions, while groundwater samples were sourced separately at different times. The samples were tested in respective laboratories.

The findings of both studies were broadly in agreement for soil samples. Organic contaminants including carbaryl, aldicarb, HCH isomers and chlorinated benzenes and heavy metals such as mercury, lead and chromium were found in most of the soil samples tested.

Both studies found contamination in groundwater too. Organic contaminants such as chlorinated benzenes and HCH isomers were detected. Among heavy metals, CSE found mercury, cadmium and lead while zinc, manganese and copper were detected by CPCB.

CHANDRA BHUSHAN / CSE

Broken boundary wall at UCIL, 2009

CHANDRA BHUSHAN / CSE

Waste dump site at UCIL, 2009

1.1 Soil contamination at UCIL

Soil inside the UCIL site was found contaminated in all the studies. The nature of chemicals found in soil samples in most studies was similar. For instance, organic contaminants such as carbaryl, aldicarb, HCH isomers, chlorinated benzenes and alpha naphthol were found in soil samples in most of the studies. Similarly, heavy metals such as mercury, lead and chromium were also commonly found (see Table 1: *Key contaminants found in soil at UCIL).*

Several places inside the UCIL site were found heavily contaminated with multiple organics and heavy metals. For instance, in several studies, either neutralisation pits or disposal area II have been found to have most of the contaminants tested for.

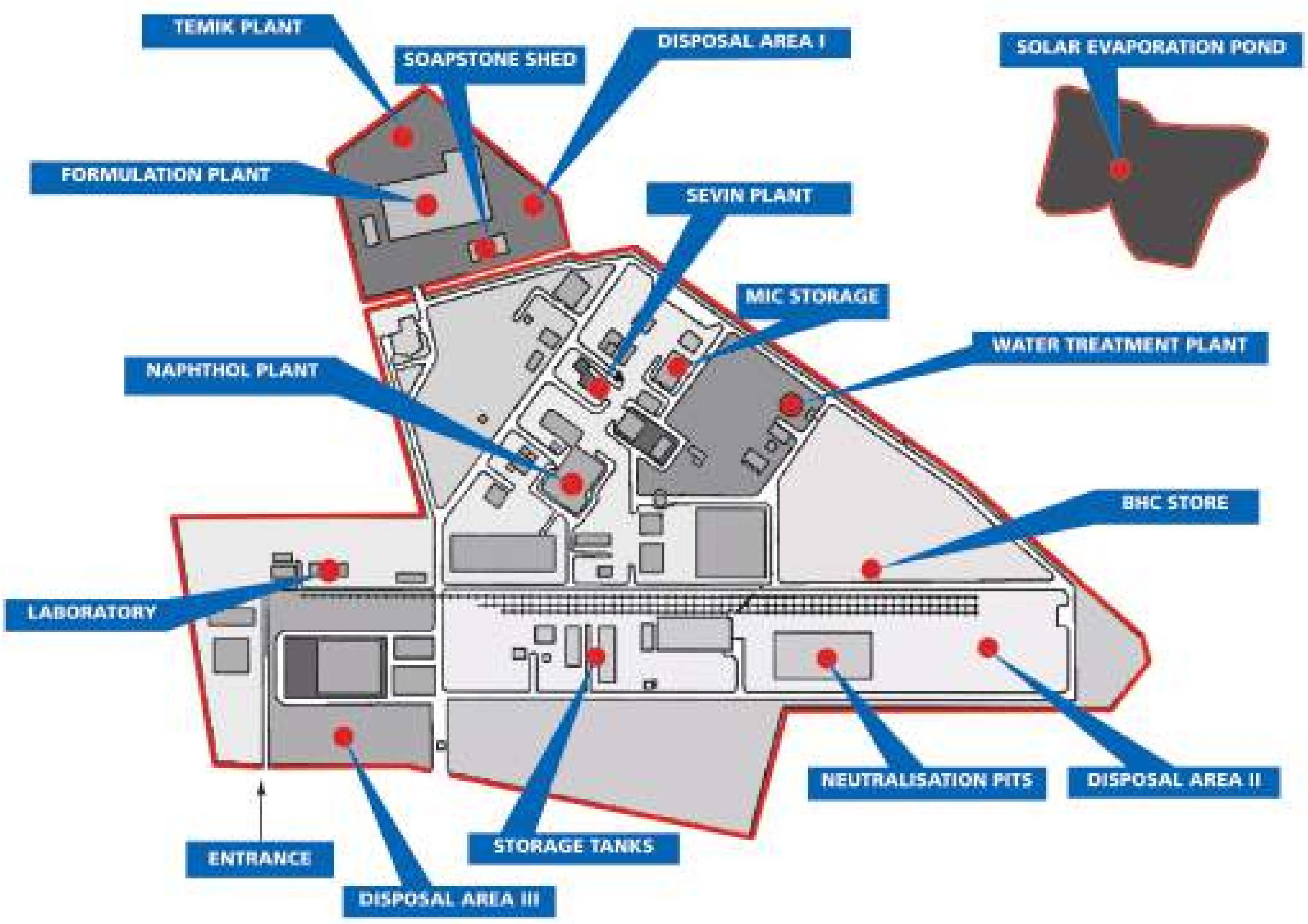
Similarly, sevin plant and formulation plant were also found contaminated with a number of organics and heavy metals in multiple studies (see Figure 1: *Places at UCIL: Contaminants tested and found in soil).*

Table 1 Key contaminants found in soil at UCIL

	IITR, 2013	NEERI-NGRI, 2010	CSE, 2009*	CPCB, 2009*
Organic contaminants				
Carbaryl	√	√	√	√
Aldicarb	√	√	√	√
HCH isomers	√	√	√	√
Chlorinated benzenes	√	√	√	√
Heavy metals				
Mercury	√	√	√	√
Lead	√	√	√	√
Chromium	√	√	√	√

*CSE and CPCB conducted a joint study in 2009

Figure 1 **Places at UCIL: Contaminants tested and found in soil**



Most of the contaminants found in soil could be linked with the production process in the UCIL plant. Organics like carbaryl, aldicarb, HCH isomers, chlorinated benzenes and alpha naphthol and heavy metals like mercury and chromium were either the final products or were being used in production process.

Contamination levels varied in different studies and maximum concentration of key contaminants found is too high (see Table 2: *Maximum concentration of key contaminants found in soil from specific places at UCIL*). Details of the contaminants are mentioned in *Annexure 2 and 3.*

The UCIL site is heavily contaminated with pesticides, chlorinated benzene compounds and heavy metals. All studies have confirmed this

Table 2 **Maximum concentration of key contaminants found in soil from specific places* at UCIL**

	Maximum concentration found in soil (ppm)
Organic contaminants	
Carbaryl	51,003
Aldicarb	7,876
Dichlorobenzenes	2,049
HCH isomers	99,700
Alpha naphthol	9,914
Heavy metals	
Mercury	1,28,000
Lead	406
Chromium	1,065

*Specific places include storage, processing and dump areas.

1.2 Groundwater contamination around UCIL

Most of the studies found groundwater from the areas surrounding the UCIL site to be contaminated with organic contaminants. Common organic contaminants were chlorinated benzenes and HCH isomers. Carbaryl, aldicarb, carbon tetrachloride and chloroform were also detected in some studies (see Table 3: *Maximum concentration of key contaminants found in groundwater around UCIL).* Also, see *Annexure 4 and 5* for all contaminants and their concentration.

A large number of contaminated areas were found to be near the railway line that passes through the north of the UCIL site. The reported direction of groundwater flow is in similar direction, i.e. towards north-east. In one study, a sample from Shiv Nagar, which is about three kms from the UCIL site, was found to be contaminated (see Figure 2: *Areas around UCIL Contaminants tested and found in groundwater).*

As in the case of soil, many contaminants found in groundwater could also be linked to the production process being followed at the erstwhile UCIL plant.

Table 3 Maximum concentration of key contaminants found in groundwater around UCIL

Organic contaminants	Maximum concentration found in water (ppb)
Carbaryl	28
Dichlorobenzenes	2,875
HCH isomers	40

Most of the studies confirmed groundwater contamination with organic contaminants. The contamination is found more towards the reported direction of the groundwater flow, i.e. north-east

Figure 2 Areas around UCIL – Contaminants tested and found in groundwater

Of the recent studies, only NEERI-NGRI in 2010 did not find groundwater to be contaminated. (see Table 4: *Key organic contaminants found in groundwater around UCIL).* They only found isolated contamination, which was attributed to the annual surface runoff during monsoon. Extremely low permeability of the black and yellow silty clay (of the order of 10^{-9} cm/sec), which is dominant in the soil strata in and around the UCIL site, was reported by NEERI to be the main reason of limited movement of contaminants towards the groundwater.

Heavy metals such as mercury, lead, chromium, manganese, zinc, nickel and copper were found in studies conducted by non-government organisations and government institutions such as IITR and CPCB.

Table 4 Key organic contaminants found in groundwater around UCIL

	IITR, 2013	NEERI-NGRI, 2010	CSE, 2009	CPCB, 2009
Carbaryl	×	×	√	×
HCH isomers	√	×	√	√
Chlorinated benzenes	√	×	√	√


CHANDRA BHUSHAN / CSE

Mercury found at UCIL, 2009

1.3 Toxic waste at the UCIL site and SEP

The waste material stockpiled and dumped at different places inside the UCIL site and outside in the SEP has not been tested extensively. In limited studies within the UCIL site, the waste was found to contain a wide range of chemicals in high concentrations. Carbaryl, aldicarb, HCH isomers and alpha naphthol were most common organic contaminants found. Among heavy metals, manganese, zinc, copper, nickel, lead and chromium were found in these studies. Also, waste dumped in the SEP, particularly the landfill needs to be assessed further (see Box: *Solar evaporation pond – Need for more studies)*

As reported, a huge amount of waste is known to be dumped by the UCIL during 1969-84 (see Table 5: *Waste dumped at the UCIL site during 1969-1984 – Key contaminants).*

Table 5 Waste dumped at the UCIL site during 1969-1984 – Key contaminants

Chemicals	Quantity (MT)
Aldicarb	2.0
Alpha napthol	50.0
Carbaryl	50.00
Carbon tetrachloride	500.00
Mercury	1.0
Naphthalene	50.00
Ortho dichlorobenzene	500.00

Source: T. R. Chauhan, Former Plant Operator, UCIL

Limited testing has been done on waste dumped at the UCIL site and SEP area. Results of the testing in SEP area are largely contrary

Solar evaporation pond – Need for more studies

The nature and level of contamination at SEP area has not been studied extensively. Soil and waste samples from the area have been tested in some of the studies but with limited agreement.

The SEP area lies at the north of the UCIL site. In mid 1990s, waste from two ponds was excavated and dumped into the third pond (secured landfill), the liners of which were found to be damaged/removed in subsequent studies.

CHANDRA BHUSHAN / CSE

Solar evaporation pond area, 2009

Characterisation of waste lying at the SEP area was conducted by NEERI in 1990. The study mentions that only neutralised wastewater was being dumped at the SEP, which left residues after evaporation. Characterisation of this residue showed presence of inorganic contaminants such as salts of sodium, calcium and magnesium. Only limited organic contaminants were found in this residue. Soil samples could not be collected from the landfill as it would have required breaking the liners.

Some studies that were conducted later tested only a limited number of soil and waste samples from the SEP area. However, in almost all cases, organic contaminants such as carbaryl, aldicarb, chlorinated benzenes and alpha naphthol and heavy metals like mercury, chromium and lead were found in the samples.

In 2003, a CPCB team that visited the UCIL site to suggest measures for safe disposal of waste, noted that the waste lying at the landfill in the SEP area was mostly sediment, which was inorganic in nature.

Overall, gaps in the studies are evident. Studies conducted after NEERI report of 1990 have shown contrary results. These studies too had limitations in terms of number of samples tested. Therefore, a thorough characterisation of the waste lying at the SEP needs to be done.

1.4 Plant, machinery and structure at UCIL

Indian Institute of Chemical Technology was commissioned by the government of Madhya Pradesh, to develop a technical and tender document for detoxification, dismantling and decommissioning of the UCIL plant.

The chemicals used, site and the structure that needed to be dismantled were studied and a detailed plan was proposed. The study spotted following areas under the scope of work:

- Methyl isocyanate (MIC) plant, sevin plant, sevin product bagging area
- Tank farm storage areas – MIC, alkali, monomethyl amine
- Chloroform, chlorine and chlorine compressor room
- Utility block – chilling plants
- Flare stack and adjacent areas
- Pipe rack and its structure

The report proposed dismantling after in-situ detoxification. The dismantling as proposed is to begin with pipelines followed by the equipments and finally the structure. It should initiate from top floor and proceed to the ground floor and involve suitable cutting of the columns and beams into small sections. Broken and completely corroded equipment and pipelines are suggested to be removed and directly soaked in an alkali pit for detoxification.

Decommissioning is also proposed but only after detoxification. As suggested, it should be done by cutting components into pieces to make them unfit for reuse.

Indian Institute of Chemical Technology recommended detoxification, dismantling and decommissioning of the UCIL plant, machinery and structure

CHANDRA BHUSHAN / CSE

Plant machinery at UCIL, 2009

2 DELIBERATIONS IN THE EXPERT ROUNDTABLE

CSE organised a two-day roundtable meeting on April 25-26 at New Delhi. For the first time, such a discussion was held, wherein active participation was observed among experts from concerned CSIR institutes such as NEERI, IICT, IITR that have comprehensively studied and reported on this in the past, CPCB – which is actively involved at present, several IITs, hazardous waste management companies, and affected community from Bhopal.

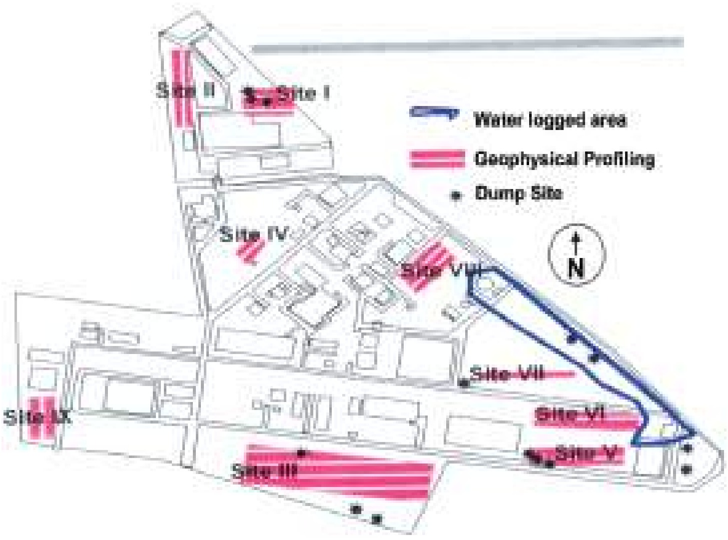
The deliberations focused on four core issues:

- Contamination and remediation of soil
- Contamination and remediation of groundwater
- Toxic waste stored at the UCIL site
- Plant, machinery and fate of the UCIL site

2.1 Contamination and remediation of soil

There was an agreement within the group about the presence of hotspots of contamination inside the UCIL site including dump-sites and other places of left over and stored chemicals near various chemical plants and storage sheds. It was noted that an exercise done in 2005 by M/s Ramky Ltd. that involved excavation of waste dumped at several places within the UCIL site was incomplete and there was a possibility of finding more waste at such dump sites. Further, it was also observed that all dump sites may not have been discovered yet. A NEERI-NGRI study in 2010, suspected several dump sites (see Figure 3: *Suspected dump locations at UCIL)*. The group was of the opinion that more dumpsites could be found as a significant part of the site, which is under vegetation and waterlogged has not been investigated. This was considered as a sufficient reason for an additional study.

Figure 3 **Suspected dump locations at UCIL**



Source:Assessment and Remediation of Hazardous Waste Contaminated Areas in and aroud M/s Union Carbide India Limited, Bhopal, NEERI-NGRI, 2010

It was collectively agreed that there is an uncertainty on the overall volume of soil that needs to be remediated. It is due to the lack of clarity on the hotspots and depth of contamination, incomplete excavation of already identified dump sites, and limited information on the waste in the SEP area. This limited understanding on the volume of the contaminated soil was considered to be a key factor in selection of a technology for soil remediation.

Selection of remediation technology is linked to the volume of the contaminated soil. There is a high possibility of several unexcavated dump sites at the UCIL site. Lack of clarity on the extent of contamination at SEP further adds to this uncertainty over volume of the contaminated soil

Another important issue discussed by the group was the depth of contamination. NEERI-NGRI study in 2010, found that the maximum depth of contamination was two meters at most of the places. A certain section of the group opined that the contaminants could be found at more depth. Considering about 35 hectares of UCIL plant site and 14 hectares of the SEP area, it was observed that depth of contamination would be important to assess the magnitude of the required remediation activity and selection of technology option thereby.

Also, the nature and volume of waste present in the SEP area remained uncertain in the discussion due to lack of studies conducted on this area.

Both immediate and long-term measures of remediation were discussed. The immediate need to secure the site from access to nearby residents and children in particular, was emphasised by all. The group also discussed the possibility of creating a temporary facility at the UCIL site, which could be used to store waste from the UCIL site as well as from SEP area. It was understood that after the waste is safely stored it can be characterised and remediation method could be selected accordingly.

Among the long-term measures, secured landfill, encapsulation and incineration were discussed. It was proposed that prior to selection of one particular method, a basket of remediation methods should be considered based on soil characterisation.

CHANDRA BHUSHAN / CSE

Contaminated water source near railway line (North of UCIL), 2009

Clarity is required on presence, extent and additional sources of groundwater contamination. Moreover, there was a dispute over a very low level of soil permeability just beneath the site, as reported by NEERI-NGRI study. Most agreed that surface runoff is not the only source of contamination

2.2 Contamination and remediation of groundwater

The deliberations focused on the role of permeability of soil, surface runoff, extent of lateral spread of contamination, immediate containment and long-term remediation measures.

Due to extremely low permeable nature of black and yellow silty clay in the area, the possibility of contamination due to percolation was ruled out by some experts. This was also cited by few as the basis of not finding contaminants in the groundwater even after about three decades. Surface runoff was proposed as a possible reason of contamination by these experts.

The group however, was divided on this issue as it was difficult to believe that presence of such low levels of soil permeability just beneath the site was a matter of sheer chance. The group agreed on the urgent need of containing annual contamination due to surface runoff but was not convinced on it being the only source of contamination.

About the groundwater flow direction, it was noted that presence of a hump in the locality may be leading to its flow in different directions. However, it was agreed by most that general direction of flow is towards north-east of the UCIL site. Most contaminated areas were also found in the same direction.

It was noted that the waste lying at the SEP area has not been satisfactorily investigated as a possible source of groundwater contamination. A section of the group believed it to be the key cause of increasing lateral spread of contaminants, which to a certain extent is evident through the geographical pattern of the findings across several years.

It was also suggested that certain contaminants such as dense non aqueous phase liquid (DNAPL) may settle down at the bottom of the aquifer, thereby not getting detected. It was agreed that the understanding of transportation flow of contaminants is still incomplete.

Overall, the group was of view that many critical issues related to groundwater contamination and therefore its remediation are not satisfactorily explained by the studies done so far. Considering the gaps in the existing findings more studies are required.

2.3 Toxic waste stored at the UCIL site

The waste excavated, packed and kept at the UCIL site in 2005 by M/s Ramky Limited, has been a sole point of discussion in recent times (see Box: *Road to incineration – about 350 tonnes of waste).* The deliberations revolved around incineration of this waste and the overemphasis on this in comparison to the overall problem.

There was a lack of clarity about the volume and constituents of the waste that has been packed and kept at the site. It was finally agreed that as of now, the packed waste amounts to about 350 tonnes (see Table 6: *Contents of packed waste at UCIL*). Besides presence of 164 tonnes of excavated soil, the reported segregation of overall constituents was found to be varying to a certain extent and leading to a confusion. Considering the volume of the excavated soil, it was deemed necessary to characterise it before incineration. It was also agreed that whatever data is available on charactersation of this waste, particularly the excavated soil, should be made public and further characterisation is to be done if required.

The feasibility of incineration as an option was also discussed. It was observed that the excavated soil may not be incinerable as its calorific value is less than standard minimum calorific value of incinerable material. It was proposed by few, that the whole waste could be mixed together before incineration so that the overall calorific value could be more than the standard. This was not agreed by many.

Table 6 Contents of packed waste at UCIL

Contents	Amount (MT)
Sevin residue + Naphthol residue	95
Reactor residue	30
Semi processed pesticides (HCH isomers mainly)	56
Excavated soil	**164**

Source: Minutes of ninth meeting of task force held on October 16, 2006

Road to incineration – about 350 tonnes of waste

Since 2005, three different places in India including Ankaleshwar in Gujarat, Nagpur in Maharashtra and Pithampur in Madhya Pradesh have been considered for incineration of toxic waste stored and packed at UCIL, which is estimated to be about 350 tonnes. At all these places, the proposal had to be withdrawn after the protests from local community. In 2012, a proposal was made by GIZ to transport this waste to Germany for incineration. This proposal was later withdrawn. Finally, incinirator at Pithampur is being considered.

Meanwhile, CPCB has conducted six trials with waste from paint and pharmaceutical industry to stabilise the Pithampur incinerator. As per a latest Supreme Court order on May 08, 2013, about 10 weeks of time is allowed to conduct trial incineration with similar waste from Hindustan Insecticides Limited (HIL), Kerala.

In 2005, M/s Ramky Limited, as directed by the government of Madhya Pradesh, collected, excavated and packed this waste. However, NEERI-NGRI in 2010, reported that the excavation done was incomplete and there could be more waste lying at these dumps. Also, what exactly lies in the excavated soil which is about half of this waste is yet to be ascertained.

CHANDRA BHUSHAN / CSE

Waste packed and stored at UCIL, 2009

CHANDRA BHUSHAN / CSE

Waste packed and stored at UCIL, 2009

Table 7 Select performance indicators – CPCB trials at Pithampur incinerator

Parameters	Prescribed standards	July, 2010	Nov, 2010	April, 2012	June, 2012	Nov-Dec, 2012	Jan, 2013
Particulate matter (mg/Nm^3)	**50**	**168.9**	**465.4**	**134.8**	16.09	41.85	39.89
CO (mg/Nm^3)	**100**	**188.9**	**125.6**	**3994.7**	10.63	12.08	23.21
CO_2 (%)	**7**	**7.9**	2.4	**8.2**	**7.95**	**7.2**	**7.8**
Dioxins and furans (Teq*/Nm^3)	**0.1**	**16.32**	**11.60**	**26.72**	**6.8**	**4.87**	0.08
Heavy metals (Sb, As, Pb, Cr, Cu, Mn, Ni, V) (mg/Nm^3)	**0.5**	**17.93**	**0.79**	**3.83**	**0.92**	0.4	0.48

* Teq - Toxic equivalents; **Source:** Affidavit filed in Supreme court by Ministry of Environment and Forests

The waste dumped at the UCIL site has not been properly excavated. 350 tonnes of waste is just a part of the total waste that is still dumped inside the site and at the SEP

Out of the six trials conducted by CPCB on the incinerator at Pithampur, except the latest trial, five have failed to comply with emission standards (see Table 7: *Select performance indicators – CPCB trials at Pithampur incinerator).*

The group discussed whether further trials should be allowed taking into account prior results of incineration and presence of a village within 500 meters. It was agreed that continuous trials with waste similar to that stored at UCIL are required for the Pithampur incinerator to be stabilised. The trials conducted so far, involved waste from paint and pharmaceutical industries, which was different than the waste lying at the UCIL site. The group was informed that the next proposed trial is to be done with about 10 tonnes of similar waste from HIL in Kerala.

The group agreed that CPCB, which has been monitoring the performance of incinerator at Pithampur, should continue doing so. Considering the existing lack of trust between the stakeholders, it would be useful to include the local community in the process. A third party monitoring agency may also be involved.

Most of the participants agreed that 350 tonnes of waste is just one small part of the overall problem and the major issue is identification of other dump sites at the UCIL site and estimating the total volume of toxic waste at these sites and SEP. The group agreed on incinerating the incinerable waste after the performance of the Pithampur Incinerator is stabilised. There was a consensus on appropriate disposal of the remaining waste.

2.4 Plant, machinery and fate of the UCIL site

The session involved deliberation on different possibilities over the fate of the UCIL site. IICT had conducted a detailed study on decontamination, dismantling and decommissioning of the plant and suggested that the structures at the site should be completely dismantled.

The possibility of converting the site into a memorial was widely agreed. The entire group wished the site to be a memorial for the victims as a mark of respect and for future generations to know about it. Experts opined that the memorial could include certain structures of the plant after preservation.

Subsequently, the concept of creating a centre of excellence for industrial disaster management and/or hazardous waste management along with memorial was well received and agreed by all.

For the purpose of a creating a memorial, technical possibility of preserving the following was agreed upon:

- MIC plant including the vent
- Vent scrubber including the vent
- Storage tanks
- Control room

There is a consensus on conversion of the site to a memorial and a center of excellence for industrial disaster management and/or hazardous waste management

SAYANTAN BERA / CSE

Plant structure at UCIL, 2009

3 ACTION PLAN

Based on the consensus over available information on several aspects, the expert group collectively finalised an action plan to address the decontamination and remediation issue.

It was emphasised that the recommended action plan needs to be time-bound and should not pile up over those from the past. Further, it was considered critical to recognise and address the existing institutional logjam, set up a fast track transparent mechanism with CPCB as the nodal supervisory agency and involve local community in the entire process.

IMMEDIATE MEASURES

3.1 SECURING THE SITE AND PREVENTING ANNUAL SURFACE WATER RUNOFF

Fencing and guarding of the UCIL site and landfill area within the SEP to prevent access to people

Repeatedly broken boundary walls of the UCIL site and lack of security personnel provides uninterrupted access to local people. Considering the presence of toxic waste, dump sites and contaminated machinery, this is a cause of serious health concern, particularly for children, who are found playing in the premises.

TIMEFRAME: IMMEDIATE

Stopping construction at the SEP area

There is a risk of the land in the SEP area being used by the owners for residential purposes, which at present may not be suitable due to its contaminated nature.

TIMEFRAME: IMMEDIATE

Measures to be taken to protect annual surface water runoff from the site during monsoon

Every year the areas around the UCIL site gets flooded with the runoff from the site during the monsoon. Local people have been reporting health hazards which they attribute to this contaminated water. One suggestion is to collect the rain water at the lowest point in a sump and an ex-situ treatment could be done before it leaves the area.

TIMEFRAME: THREE MONTHS

3.2 EXCAVATION, RECOVERY AND CHARACTERISATION OF WASTE DUMPED AT THE UCIL SITE

Clearing vegetation and dewatering the site

Dense vegetation and waterlogging at the site in the past has made it difficult to explore the presence of dumped waste at the site. Vegetation is to be removed only to the extent of facilitating these studies and not compromising on its capability to prevent further spread of contamination. The recovered water may need to be tested/treated prior to disposal.

TIMEFRAME: ONE MONTH (POST MONSOON)

Identification and refurbishment of a temporary storage area for the excavated waste

A temporary area to store the excavated waste is to be identified and refurbished well before the excavation and recovery of waste. It would facilitate determination of volume and characterisation of the waste and secure it to prevent spread of contamination. This could also be used to store the waste excavated from the dump site within the SEP area. The storage area could be in addition to the existing and may be considered for further use as a permanent encapsulation.

TIMEFRAME: THREE MONTHS

Excavation and recovery of dump materials from already identified and new sites

It has been reported and discussed that excavation of the site done by M/s Ramky Limited in 2005 was incomplete. NEERI-NGRI study in 2010 spotted four new dump sites that were not known earlier. It is important to excavate all these sites properly to estimate the actual volume of waste and contaminated soil present at the site.

TIMEFRAME: THREE MONTHS

Recovery of mercury present in drains, pan filters, soil with the help of local community

Local people have been reporting presence of dumped mercury at the site. Mercury is known to be highly toxic and its presence poses threat to their health. Appropriate containers should be used to contain the mercury.

TIMEFRAME: THREE MONTHS

Characterisation and inventorisation of the collected waste for proper treatment and/or disposal

Considering the uncertain volume and composition of the waste, this would help in selecting the technology options for remediation/disposal.

TIMEFRAME: SIX MONTHS

3.3 CHARACTERISATION AND INCINERATION OF THE STORED WASTE AT THE UCIL SITE

Trial at the Pithampur incinerator with ten tonnes of similar waste from HIL, Kerala

Considering that five of the six trials conducted till date by CPCB have failed to comply with the norms, it is necessary to conduct further trials taking local community in confidence. A third party monitoring institution such as an IIT could be involved. The incinerator performance is to be stabilised during the trials, which so far involved waste from pharmaceutical and paint industries. This waste was not similar to the waste at UCIL, Bhopal.

TIMEFRAME: **THREE MONTHS**

Characterisation results of the stored waste to be made public and if required, further characterisation and inventorisation to be done in parallel with the trials

There is a lack of clarity on the waste characterisation, particularly the 164 tonnes of excavated soil. If required, further characterisation of the packed waste is to be done to be sure about the possible remedial options.

TIMEFRAME: **THREE MONTHS**

Waste with high calorific value and hazardous in nature to be incinerated with continuous stack monitoring and remaining waste to be dealt with suitable decontamination and/or remediation measures

If the characterised waste is found to be incinerable and the performance of the incinerator is stabilised, it is suggested to incinerate the waste already packed. It should be done under the supervision of CPCB.

TIMEFRAME: **SIX MONTHS**

MEDIUM-AND LONG-TERM MEASURES

3.4 GROUNDWATER CONTAMINATION ASSESSMENT AND REMEDIATION OUTSIDE THE UCIL SITE

Field investigation and lab analysis of the groundwater

Considering the gaps in earlier findings, a thorough assessment of the type of contamination and its lateral spread around the UCIL should be done. This would also help in understanding the technology options and magnitude of the remediation work. Geohydrological study at the site and SEP to know the sources of contamination may also help in developing clarity on this.

TIMEFRAME: **ONE YEAR**

Possibility of hydraulic containment to be explored as an interim measure

Hydraulic containment is an interim measure which will stop the contamination from leaving the UCIL site and the SEP area. This could be deployed while the site is being decontaminated.

TIMEFRAME: **SIX MONTHS TO ONE YEAR**

Remediation/containment plan to be developed and implemented

Based on the field investigation and lab analysis, an appropriate containment/remedial plan should be developed and implemented.

TIMEFRAME: **TWO TO THREE YEARS**

3.5 CHARACTERISATION AND REMEDIATION OF WASTE DUMPED IN LANDFILL IN THE SEP AREA

Characterisation of waste and development of a basket of disposal/decontamination/remediation options

Waste dumped at the landfill in the SEP is to be characterised, followed by an assessment and development of a basket of suitable options. The landfill is damaged and this waste could be recovered and stored in a temporary storage within the UCIL site considering the need to estimate the volume and nature of waste. Moreover, the SEP area is to be secured and made inaccessible to local community.

TIMEFRAME: **ONE YEAR**

Disposal/remediation of the waste and decontamination of the landfill area

Remediation plan is to be finalised based on considerations of time schedule, life-cycle cost, overall efficiency and sustainability of the alternatives. Considering SEP as a potential source of contamination, it would be critical to complete the remediation as soon as possible.

TIMEFRAME: **ONE TO TWO YEARS**

3.6 REMEDIATION OF ENTIRE SEP AREA

Assessment of the need of geohydrological and contamination analysis based on previous reports

It was agreed that SEP area is not satisfactorily studied. However, all previous reports that have studied SEP are to be revisited to finalise the need of further studies. Critical data gaps, if present, should be identified and addressed, in parallel, to the extent possible.

TIMEFRAME: **THREE MONTHS**

If required, SEP to be studied for waste characterisation and source of groundwater contamination

Considering the limited information on SEP and groundwater contamination, it was considered important to be sure of the possibility of connection between the two.

TIMEFRAME: **ONE YEAR**

Development and implementation of the remediation plan keeping residential purpose in mind

It was realised during the discussions that the SEP area is in the middle of the city and can be used for residential purposes if remediated properly.

TIMEFRAME: **THREE TO FIVE YEARS**

3.7 DETOXIFICATION, DISMANTLING AND DECOMMISSIONING OF THE UCIL PLANT, MACHINERY AND STRUCTURE

MIC plant including the vent, vent scrubber, storage tanks and control room to be strengthened and preserved

It came out during the discussion that these parts of the plant are relatively in better condition. It was a consensus to preserve these as part of a memorial after decontamination as suggested by IICT.

TIMEFRAME: TWO YEARS

Remaining parts of the site to be decontaminated, dismantled and decommissioned as recommended by IICT

Remaining plant structure is a hindrance in exploring new dump sites and is not strong enough to preserve. It is therefore necessary to decontaminate and dismantle such structures as proposed by IICT.

TIMEFRAME: TWO YEARS

3.8 REMEDIATION AND FATE OF THE UCIL SITE

Geohydrological and contamination studies for the site based on stratified judgmental sampling

A detailed analysis on level and possible sources of groundwater contamination (including free phase organic compound i.e. NAPL) should be conducted with involvement of local community. This could be done after the site is cleared of vegetation, structure and waterlogging.

TIMEFRAME: TWO YEARS

Development of a basket of decontamination/disposal methods accordingly

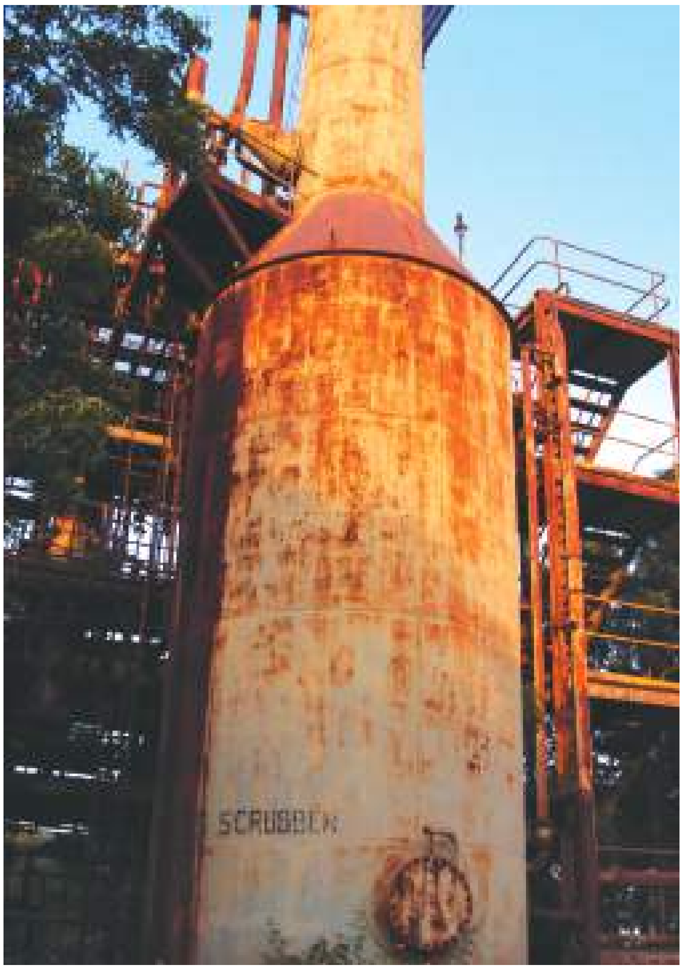
Incomplete understanding of geohydrology and contamination level at the site makes it difficult to shortlist one particular method of decontamination. A basket of methods need to be developed while deciding upon the final decontamination method.

TIMEFRAME: TWO TO THREE YEARS

Remediation plan based on future use as memorial and a centre of excellence

It was agreed by the group that some parts of the UCIL site must be preserved as a memorial. The rest of the area can be used for developing A centre of excellence for industrial disaster and/or hazardous waste management

TIMEFRAME: TWO TO THREE YEARS



CHANDRA BHUSHAN / CSE

Vent gas scrubber, 2009

An international competition on master planning for conversion of the site

An international competition is expected to bring out the best and most innovative solution for master planning and linking it with the remediation of the site. It may also raise awareness about the whole issue globally. It should be done along with the local community.

TIMEFRAME: ONE YEAR

Implementation of the remediation plan and conversion of the site to a memorial and centre of excellence

It should be connected with the remediation of the site and long-term monitoring

TIMEFRAME: THREE TO FIVE YEARS

Summary of Action Plan

IMMEDIATE MEASURES	
SECURING THE SITE AND PREVENTING ANNUAL SURFACE WATER RUNOFF	**THREE MONTHS**
Fencing and guarding of the UCIL site and landfill area within the SEP	Immediate
Stopping construction at the SEP area	Immediate
Measures to be taken to protect annual surface water runoff from the site during monsoon	Three months
EXCAVATION, RECOVERY AND CHARACTERISATION OF WASTE DUMPED AT THE UCIL SITE	**SIX MONTHS**
Clearing vegetation and dewatering the site	One month
Identification and refurbishment of a temporary storage area for excavated waste	Three months
Excavation and recovery of dump materials from already identified and new sites	Three months
Recovery of mercury present in drains, pan filters and soil with the help of local community	Three months
Characterisation and inventorisation of the collected waste for proper treatment and/or disposal	Six months
CHARACTERISATION AND INCINERATION OF THE STORED WASTE AT THE UCIL SITE	**SIX MONTHS**
Trial at the Pithampur incinerator with ten tonnes of similar waste from HIL, Kerala	Three months
Characterisation results of the stored UCIL waste to be made public; if required, further characterisation and inventorisation to be done in parallel with the trials	Three months
Waste with high calorific value and hazardous in nature to be incinerated with continuous stack monitoring; remaining waste to be dealt with suitable decontamination/remediation measures	Six months
MEDIUM- AND LONG-TERM MEASURES	
GROUNDWATER CONTAMINATION ASSESSMENT AND REMEDIATION OUTSIDE THE UCIL SITE	**TWO TO THREE YEARS**
Field investigation and lab analysis of the groundwater	One year
Possibility of hydraulic containment to be explored as an interim measure	Six months to one year
Remediation/containment plan to be developed and implemented	Two to three years
CHARACTERISATION AND REMEDIATION OF WASTE DUMPED IN LANDFILL IN THE SEP AREA	**ONE TO TWO YEARS**
Characterisation of waste and development of a basket of disposal/decontamination/remediation options	One year
Disposal/remediation of the waste and decontamination of the landfill area	One to two years
REMEDIATION OF ENTIRE SEP AREA	**THREE TO FIVE YEARS**
Assessment of the need of geohydrological and contamination analysis based on previous reports	Three months
If required, SEP to be studied for waste characterisation and source of groundwater contamination	One year
Development and implementation of the remediation plan keeping residential purpose in mind	Three to five years
DETOXIFICATION, DISMANTLING AND DECOMMISSIONING OF UCIL PLANT, MACHINERY AND STRUCTURE	**TWO YEARS**
MIC plant including the vent, vent scrubber, storage tanks and control room to be strengthened and preserved	Two years
Remaining parts of the site to be decontaminated, dismantled and decommissioned as recommended by IICT	Two years
REMEDIATION AND FATE OF THE UCIL SITE	**THREE TO FIVE YEARS**
Geohydrological and contamination studies for the site based on stratified judgmental sampling	Two years
Development of a basket of decontamination/disposal methods accordingly	Two to three years
Remediation plan based on future use as a memorial and a centre of excellence	Two to three years
An international competition on master planning for conversion of the site	One year
Implementation of the remediation plan and conversion of the site to a memorial and a centre of excellence	Three to five years

Annexure 1 List of the studies conducted

Year	Organisation	Study
2013	IITR	Analysis of Soil and Groundwater Samples in Bhopal
2010	NEERI and NGRI	Assessment and Remediation of Hazardous Waste Contaminated Areas in and around M/s Union Carbide India Ltd., Bhopal
2010	IICT	Technical and Tender Document for Detoxification, Decommissioning and Dismantling of Union Carbide Plant
2009	CSE	Contamination of Soil and Water Inside and Outside the Union Carbide India Limited, Bhopal
2009	CPCB	CPCB study (with CSE)
2002	Greenpeace International	Chemical Stockpiles at Union Carbide India Limited in Bhopal: An Investigation
2002	Fact Finding Mission & Shrishti	Surviving Bhopal: Toxic Present, Toxic Future
2001-02	People's Science Institute	Groundwater Contamination near the Union Carbide Plant at Bhopal
1999	Greenpeace International	The Bhopal Legacy
1997	NEERI	Assessment of Contaminated Areas due to Past Waste Disposal Practices by EIIL, Bhopal
1996	State Research Laboratory, PHED, MP	Report of Chemicals found in Water for Communities around UCIL premises
1992	NEERI	Process Package for Disposal of SEP Contents at UCIL, Bhopal
1990	Bhopal Group for Information and Action	Union Carbide in Bhopal, India-The lingering legacy
1990	NEERI	Assessment of Pollution Damage due to Solar Evaporation Ponds at UCIL, Bhopal
1989	Union Carbide Limited	Site Rehabilitation Project–Bhopal Plant

Annexure 2 Summary of studies: Organic contamination in soil (ppm)

Sampling spot	IITR, 2013	NEERI-NGRI, 2010	CSE, 2009	CPCB, 2009	Greenpeace, 2002	Fact finding Mission, 2001-02	Greenpeace, 1999	NEERI, 1997
Temik plant	0.366 (Car) 0.809 (HCH) 0.324 (DCB)	24.3 (Car) 923 (Ald) 36.36 (HCH) 0.000097 (DCB) 42.7(Nap)	29.17 (HCH) 4.94 (TCB)	0.03 (Ald) 21.17 (HCH)	Not tested	Not tested	Not tested	
Formulation plant	0.295 (Car) 2572.67 (HCH) 3.774 (Nap)	1.3 (Car) 3.734 (Ald) 1.152 (HCH) 1.9(Nap)	7.47 (Car) 190.69 (Ald) 3119.37 (HCH) 2048.53 (DCB) 507.05 (TCB)	5.25 (Car) 6193 (HCH)	0.001122(Car) 99700 (HCH)	Not tested	Detected (HCH)	
Soapstone shed	0.201 (Car) 1.431 (HCH) 0.209 (DCB) 2.186 (Nap)	24.6 (Car)) 0.76 (HCH) 14.94(Nap)	Not tested	Not tested	0.001839 (Car) 38.5 (HCH)	Not tested	Not tested	
Sevin plant	0.172 (Car) 0.39 (HCH) 0.15 (Nap)	0.126 (Car) 0.77 (HCH) 0.000017 (DCB) 0.54 (Nap)	412.83 (HCH) 26.93 (DCB) 23.72 (TCB)	13.468 (HCH)	0.000083 (Car) 5010 (HCH)	1.6878 (HCH) 0.1292 (DCB) 0.1927 (TCB)	Detected (HCH)	
MIC storage	0.286 (Car) 0.018 (HCH) 3.549 (Nap)	18.3 (Car) 3.778 (Ald) 0.118 (DCB) 0.267 (Nap)	Not tested	Not tested	Not tested	Not tested		
BHC store	1.004 (Car) 36.783 (HCH) 0.918 (DCB) 3.195 (Nap)	2.48 (Car) 6.17 (HCH) 1.55 (Nap)	Not tested	Not tested	0.000962 (Car) 22100 (HCH)	Not tested	Not tested	
Water treatment plant	0.588 (Car) 4.733 (HCH) 2.499 (DCB) 5.612 (Nap)	0.174 (Car) 1.037 (HCH) 0.000013 (DCB) 0.511(Nap)	Not tested	Not tested	Not tested	Not tested	Not tested	
Neutralisation pits	0.504 (Car) 0.01 (HCH) 0.203 (DCB) 1.588 (Nap)	10729 (Car) 3.884 (Ald) 13.34 (HCH) 0.165 (DCB) 1460 (Nap)	Not tested	Not tested	Not tested	Not tested	Detected (HCH) Detected (DCB)	53 (Car) 5105 (Ald) 23 (Nap)
Storage tanks		2.43 (HCH)			Not tested	Not tested		
Laboratory	0.127 (Car) 9.368 (HCH)	10.77 (Car) 0.31 (HCH) 0.11 (DCB) 32.9 (Nap)	Not tested	Not tested	Not tested	Not tested	Not tested	
SEP		6.88 (Car) 8.15(Ald) 2.55 (HCH) 3.51 (Nap)	19.83 (HCH) 2.68 (DCB)	0.137 (Car) 1.479 (HCH)	87.5 (DCB) 59 (Nap)	0.0358 (HCH) 0.1215 (DCB)		

Continued…

Annexure 2 …continued

Sampling spot	IITR, 2013	NEERI - NGRI, 2010	CSE, 2009	CPCB, 2009	Greenpeace, 2002	Fact finding Mission, 2001-02	Greenpeace, 1999	NEERI, 1997
Disposal Area I	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	51003 (Car) 116 (Ald) 210 (HCH) 9914(Nap)
Disposal Area II			56.17 (Ald) 1162.19 (HCH) 2.35 (DCB)	333.5 (Car) 269.12 (HCH) 6.34 (DCB)	Not tested			4162 (Car) 7876 (Ald) 82 (HCH) 1024 (Nap)
Disposal Area III	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	462 (Car) 58 (Nap)

Note: Not tested (mentioned wherever specified or can be inferred)
NEERI 1997 report primarily segregates the entire area into three disposal areas and rest of the area
Abbreviations and symbols: Car – Carbaryl, Ald – Aldicarb, HCH – Hydrochlorocyclohexane, DCB – Dichlorobenzene, TCB – Trichlorobenzene, Nap – Alpha Naphthol

Summary

At least eight studies tested for organic contamination is soil and waste samples from UCIL site. An analysis of findings of these showed that carbaryl, aldicarb, HCH isomers, and dichlorobenzene were present in significant quantities at various spots. Some spots such as formulation plant and neutralization pits were found heavily contaminated. They were found contaminated in almost all the studies. For carbaryl, maximum concentration recorded among these spots was 51003 ppm which was found by NEERI in 1997 at disposal area I. The same study found 9914 ppm, maximum concentration of alpha naphthol and 7876 ppm of aldicarb at disposal area I and II respectively. For HCH isomers, Greenpeace found maximum concentration of about 10 percent near formulation plant in 2002. CSE in 2009 found a maximum concentration of 2048 ppm of dichlorobenzene near formulation plant.

Annexure 3 Summary of studies: Heavy metal contamination in soil (ppm)

Sampling spot	IITR, 2013	NEERI-NGRI, 2010	CSE, 2009	CPCB, 2009	Greenpeace, 2002	Fact finding Mission, 2001-02	Greenpeace, 1999	NEERI, 1997
Temik plant	0.084 (Hg) 29.614 (Cr) 88.583 (Pb)	2.22 (Cr) 4.3 (Pb)	74.14 (Hg) 297.7 (Cr) 111.78 (Pb)	48.48 (Hg) 343 (Cr) 92 (Pb)	Not tested	Not tested	Not tested	
Formulation plant	3.568 (Hg) 145.08 (Cr) 26.031 (Pb)	1.29 (Hg) 2.32 (Cr) 4.29 (Pb)	108.4 (Cr)	2.87 (Hg) 183 (Cr) 42 (Pb)	Not tested	Not tested	2.6 (Hg) 85.7 (Cr) 19.4 (Pb)	
Soapstone shed	1.547 (Hg) 26.186 (Cr) 24.047 (Pb)	2.1 (Hg) 2.97 (Cr)	Not tested	Not tested	Not tested	Not tested	Not tested	
Sevin plant	0.088 (Hg) 24.977 (Cr) 30.545 (Pb)	1.83 (Cr) 6.64 (Pb)	8188.33 (Hg) 192.13 (Cr) 84.05 (Pb)	7995.83 (Hg) 451 (Cr) 95 (Pb)	Not tested	0.152 (Cr)	128000 (Hg) 480.7 (Cr) 174.6 (Pb)	
MIC storage	31.751 (Pb)	0.1 (Hg) 3.04 (Cr) 0.98 (Pb)	Not tested	Not tested	Not tested	Not tested	Not tested	
BHC store	3.541 (Hg) 30.012 (Cr) 25.458 (Pb)	4.17 (Hg) 3.02 (Cr) 5.99 (Pb)	Not tested	Not tested	Not tested	Not tested	Not tested	
Water treatment plant	0.242 (Hg) 37.197 (Cr) 25.263 (Pb)	2.41 (Cr) 4.62 (Pb)	Not tested	Not tested	Not tested	Not tested	Not tested	
Neutralisation pits	0.098 (Hg) 29.106 (Cr) 24.46 (Pb)	3.07 (Hg) 3.97 (Cr) 7.58 (Pb)	Not tested	Not tested	Not tested	Not tested	8.1 (Hg) 520.8 (Cr) 406.3 (Pb)	101 (Cr) 11 (Pb)
Laboratory	0.089 (Hg) 34.745 (Cr) 40.547 (Pb)	1.98 (Cr) 2.41 (Pb)	Not tested	Not tested	Not tested	Not tested	Not tested	
Naphthol plant	0.255 (Hg) 38.811 (Cr) 30.926 (Pb)	0.41 (Hg) 3.8 (Cr) 2.03 (Pb)	Not tested	Not tested	Not tested	1.898 (Hg)	Not tested	
Cycle shed			Not tested	Not tested	Not tested	0.0206 (Cr)	Not tested	
SEP	0.114 (Hg) 40.809 (Cr) 95.73 (Pb)	0.30 (Hg) 5.21 (Cr) 3.53 (Pb)	18 (Hg) 1064.57 (Cr) 22.34 (Pb)	28.13 (Hg) 1110 (Cr)	0.1 (Hg) 96 (Cr) 12 (Pb)	0.5269 (Cr) 0.2767 (Pb) 17 (Pb)	1.1 (Hg) 73 (Cr)	
Disposal Area I	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	61 (Cr) 11 (Pb)	
Disposal Area II			1064.61 (Hg) 86.18 (Cr) 46.39 (Pb)	557.53 (Hg) 112 (Cr) 22 (Pb)	Not tested		58 (Cr) 10 (Pb)	
Disposal Area III	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	Not tested	36 (Cr) 7 (Pb)

Note: Not tested (mentioned wherever specified or can be inferred)

NEERI 1997 report primarily segregates the entire area into three disposal areas and rest of the area

Abbreviations and symbols: Hg – Mercury, Cr – Chromium, Pb – Lead, Ni – Nickel, Zn – Zinc, Cu – Copper, Mn – Manganese

Summary

At least eight different studies tested for presence in heavy metals in soil and waste samples from UCIL plant premises. Mercury, chromium and lead were among most common heavy metals found. The maximum concentration of mercury was found in a sample from sevin plant by Greenpeace in 1999. The sample contained more than 12 percent of mercury. CSE in 2009 found maximum concentration of 1064 ppm of chromium from a sample near solar evaporation pond. Greenpeace in 1999 also found a maximum of 406 ppm of lead in a sample from near neutralisation pits.

Annexure 4 Summary of studies: Organic contamination in groundwater (ppb)

Sampling spot	IITR, 2013	CSE, 2009	CPCB, 2009	Fact finding Mission, 2001-02	Greenpeace, 1999
J. P. Nagar	Not tested	3.1 (HCH) 0.0008 (DCB) 11.3 (Car)	0.11 (HCH)	1.8 (HCH) 9.4 (DCB)	50 (DCB)
Nawab Colony	0.688 (HCH) 2.027 (DCB)	0.4 (HCH) 0.3 (DCB)	0.72 (HCH)	1.3 (HCH) 1.2 (DCB)	2875 (DCB)
Shiv Shakti Nagar	0.251 (HCH) 9.917 (DCB)	Not tested	Not tested	Not tested	
Blue moon Colony	0.991 (HCH) 3.621 (DCB)	0.6 (HCH) 0.7 (DCB) 0.2 (Car)	Not tested	Not tested	
Atal Ayub Nagar		1.1 (HCH) 0.5 (DCB) 0.8 (Car)	0.12 (HCH) 651.91 (DCB)	2.7 (HCH) 0.8 (DCB)	
Anu Nagar	4.249 (DCB)	0.5 (HCH) 0.4 (DCB)	Not tested	40.2 (HCH) 10.4 (DCB)	Not tested
Kainchi Chhola	6.375 (DCB)	Not tested	0.56 (HCH)	3.2 (HCH) 14.7 (DCB)	Not tested
Arif Nagar	0.029 (HCH)	Not tested	Not tested	Not tested	Not tested
Prem Nagar	0.576 (HCH) 5.651 (DCB)	1.7 (HCH) 0.5 (DCB)	Not tested	Not tested	Not tested
Navjeevan Colony	0.388 (HCH) 8.271 (DCB)	Not tested	Not tested	Not tested	Not tested
Garib Nagar		1.4 (HCH) 0.9 (DCB)	0.4752 (HCH)	Not tested	Not tested
Sundar Nagar	Not tested	0.8 (HCH) 0.4 (DCB)	0.0804 (HCH)	Not tested	Not tested
New Arif Nagar		1.2 (HCH) 0.5 (DCB) 27.6 (Car) 0.5 (Ald)	Not tested	3 (HCH)	Not tested
Shakti Nagar	5.04 (DCB)	Not tested	Not tested	36.7 (HCH)	Not tested
Preet Nagar	6.411 (DCB)	Not tested	Not tested	Not tested	Not tested
Shiv Nagar	8.751 (DCB)	3.5 (DCB)	Not tested	Not tested	Not tested
Indira Nagar		Not tested	0.1038 (HCH)	Not tested	Not tested

Note: Not tested (mentioned wherever specified or can be inferred)
Abbreviations and symbols: Car – Carbaryl, Ald – Aldicarb, HCH – Hydrochlorocyclohexane, DCB – Dichlorobenzene, TCB – Trichlorobenzene, Nap – Alpha Naphthol

Summary

Groundwater was mainly found contaminated with HCH isomers and chlorinated benzenes. At least four different studies found presence of HCH isomers in groundwater samples. Similarly, at least five of the studies found dichlorobenzene present in the groundwater samples. A maximum concentration of 40.2 ppb of HCH isomers was found by Fact Finding Mission in a sample from Anu Nagar area. Similarly, a maximum of 2875 ppb of dichlorobenzene was found by Greenpeace in 1999 in a sample from Nawab colony. CSE found 27.6 ppb of carbaryl in New Arif Nagar area.

Annexure 5 Summary of studies: Heavy metal contamination in groundwater (ppb)

Sampling spot	CSE, 2009	CPCB, 2009	Fact finding mission, 2001-02	Peoples Science Institute, 2001
J. P. Nagar		1590 (Zn) 100 (Mn)	14.9 (Cr) 744.7(Ni) 49.7 (Pb)	Not tested
Nawab Colony	90 (Cd) 1220 (Pb)	50 (Cu) 1810 (Zn) 350 (Mn)	9.5 (Cr) 1800 (Ni) 11.7 (Pb)	42 (Hg)
Atal Ayub Nagar		30 (Cu) 40 (Zn)	11.7 (Cr) 56 (Hg) 1875 (Ni)	
Anu Nagar	Not tested	Not tested	293.9 (Hg) 10.7 (Cr) 903.6 (Ni) 1.3 (Pb)	70 (Hg)
Kainchi Chhola	Not tested	400 (Zn) 20 (Mn)	21 (Cr) 941.7 (Ni) 54.8 (Pb)	Not tested
Garib Nagar	Not tested	550 (Zn) 40 (Mn)	Not tested	24 (Hg)
Sundar Nagar	Not tested	480 (Zn) 20 (Mn)	Not tested	Not tested
New Arif Nagar	Not tested	Not tested	119.7 (Hg) 5.7 (Cr) 1080 (Ni) 39.8 (Pb)	40 (Hg)
Shakti Nagar	Not tested	Not tested	31.7 (Hg) 12.6 (Cr) 715.5 (Ni) 11.3 (Pb)	Not tested
Shiv Nagar	24 (Hg)	Not tested	Not tested	Not tested
Indira Nagar	Not tested	130 (Zn) 2770 (Mn)	Not tested	Not tested
Panchwati	Not tested	730 (Zn) 20 (Mn)	Not tested	Not tested
Chhola Naka	Not tested	280 (Zn) 20 (Mn)	Not tested	Not tested
SEP		Not tested	34.3 (Hg) 11.6 (Cr) 186.1 (Ni) 32.1 (Pb)	Not tested

Note: Not tested (mentioned wherever specified or can be inferred)
Abbreviations and symbols: Hg – Mercury, Cr – Chromium, Pb – Lead, Ni – Nickel, Zn – Zinc, Cu – Copper, Mn – Manganese

Summary

Groundwater in the surrounding areas of the UCIL plant was found contaminated with multiple heavy metals such as mercury, cadmium, chromium, manganese, zinc, lead and nickel. At least three of the studies found mercury contamination at different places. A highest of about 293.9 ppb of mercury was found in a sample from Anu Nagar by Fact Finding Mission in 2001-02. A highest of 1220 ppb of lead was found by CSE in a sample from Nawab colony in 2009. Fact Finding Mision in 2001-02 found a maximum of 21 ppb of chromium from a sample from Kainchi Chhola. A sample from Nawab colony was found to contain 1810 ppb of zinc by CPCB in 2009.

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