Recommendations of the International Team of Experts on the remediation of the former Union Carbide site in Bhopal (India)

Clean up of the site can be done to international standards, in a secure manner and within a foreseeable time.

An international expert team consisting of:
- Prof. Harald Burmeier, Civil Engineer, Germany
- Dr. Franz Schenker, Geologist, Switzerland
- Dr. Jurgen H. Exner, Remediation Spezialist Chemist, U.S.A

and their teams carried out an accelerated feasibility study for the cleanup of the contaminated site of the former Union Carbide plant in Bhopal, India. The team studied documents of past site investigations, the history and current situation of the Bhopal site, made a site visit, and interviewed governmental and nongovernmental organizations. The experts made recommendations for the clean up of the site including the disposal of the stockpiles still on the site, the dismantling of the remaining plants and buildings, the decontamination of the soil to residential standards, and remediation of the contaminated ground water.

This study was commissioned by Greenpeace. The work of the experts was facilitated by the logistical support provided by Greenpeace campaigners in India and in Switzerland. The Science Unit of Greenpeace (the Greenpeace Research Laboratories, University of Exeter) will engage in scientific review of the final report.

The experts have broad expertise in the assessment, planning, and supervision of remediation of hazardous waste sites by standard and innovative technologies. Their practical knowledge of pesticide and other chemical plants was used for the current feasibility study.

At a workshop in Bhopal November 4, 2004, the international experts team presented the results of their work to an audience consisting of different organizations from the government of India, the state of Madhya Pradesh, local authorities, scientific and technical experts, and representatives of different NGOs and citizens of Bhopal.

What is the current situation at the site?

- At the Bhopal plant, parts of the former pesticide factory remain, including some of the production plants, storage and disposal areas, and various buildings. In general, the facilities are in an acceptable but deteriorated state considering the time elapsed since shut down of the factory and the effects of climatic conditions.
- The site is secured with a fence, a wall, and security service but is easily accessible by people from neighborhood. More disturbingly, the site including the Solar Evaporation ponds (SEP) is used for grazing of livestock and as a playground for children.
- Visible wastes remain on the ground in many places.
- The plant is surrounded by settlements (“bastees”) with approx. 20,000 inhabitants. These areas are supplied with drinking water partly by tanker vehicles and by above ground storage tanks. Partly hand pumps are in use although wells are marked as “polluted”.

What are the main risks and environmental impacts today?

- Direct contact of the people with the chemical contaminants and hazardous wastes on the site is a great concern.
- The disposed wastes and the contaminated soil pose a long-term risk for ground water pollution.
- Knowledge of the ground water situation is generally poor, but contamination of the groundwater, which is used as a drinking water supply, has already occurred.

What is the current inventory of contaminants on the site?

- The remaining plants and buildings including the stockpiles contain multiple types of toxic organic and inorganic chemicals.
- Diverse laboratory chemicals are present and PCB in transformers and asbestos in roof and wall coverings may exist.
- Surface soil contamination exists mostly as residues of the pesticide production such as temik, hexachlorocyclohexane (HCH), sevin, naphthol, naphthalene and mercury. Solvents such as dichlorobenzene, carbon tetrachloride, and chloroform are highly likely to be present in the deeper sub soil.
- The ground water is contaminated by high concentrations of these solvents and some heavy metals.
- There are approximately 25,000 Tonnes of contaminated solid material at the site.

What are the objectives for remediation of this site?

- Site remediation has to be done with proven and low-risk technologies.
- The disposal of wastes has to be carried out with the best available technologies according to international standards.
- The Bhopal site is not recommended for experimental procedures.
- The problem of the contamination and its spread has to be solved in a foreseeable timeframe.
- The Bhopali people must have confidence in the remediation technology used.
- The impact on the surrounding population has to be minimized during remediation.
- The site must be cleaned up to residential standards even if there will be no housing.The groundwater should be cleaned up for drinking water purposes.

What types of technologies were considered for the clean up?

- State-of-the-art technologies and innovative approaches were examined.
- As a first step, feasible options were identified from the global set of remediation technologies. In the second step, these feasible options were evaluated by a series of criteria to identify optimal treatment options and treatment combinations.

What criteria were used for the technical assessment?

- The first step of the assessment considered only the criteria of effectiveness, general feasibility and acceptability.
- The second assessments used more detailed criteria to consider advantages and disadvantages of each of the technologies and to rank them. In this phase costs were entered for the first time.

What are the recommendations for the clean up?

Immediate measures:

- The first and most urgent measure is to fence and secure the site until remediation has been completed. Unauthorized access to the site including the Solar Evaporation ponds has to be prohibited. This applies especially to access by vulnerable children or by live-stock that provides food. The removal of materials of any kind should stop.
- Secondly, a supply of clean drinking water in sufficient quantities must be provided till the full remediation process has finished.

Remediation measures:

1. *Short term objectives*: Site (include the SEP) remediation to reduce risks by direct contact and further groundwater pollution:
   - Dismantling all facilities and buildings on the site. Collection of all wastes (stockpiles) and decontamination of all equipment and construction material on site. Removal of decontaminated buildings and plants.
   - Excavation of wastes and contaminated soil.
   - On site pretreatment if necessary (breaking or sieving.)
   - On site decontamination:
     - Option 1: Thermal desorption
     - Option 2: Microbiological treatment
   - Decision about Option 1 or 2 after testing on representative mixtures of site contaminants
   - Waste management:
     - Backfilling decontaminated soils on site
     - Landfill for decontaminated solar evaporation pond (SEP) sludges on site
     - Packaging and transportation of residues from remediation (high concentrated contaminants):
       - Cleaning residues from dismantling
       - Pure wastes from stockpiles
       - Residues from thermal desorption (in case of option 1)
     - Hazardous wastes treatment using an appropriate technique. Currently, the incineration of these wastes in developed countries is the most immediately available option, though developing; innovative methods should be tested for suitability and full-scale implementation.
2. *Long term objective*: Ground water remediation to provide use of ground water as clean drinking water:
   - Pumping of contaminated ground water
     - Location and depth depends on specific site investigation
     - Pumping rate according to geological survey and testing
   - Pumping of DNAPL (Dense non aqueous phase liquids) phase
     - In case site investigation shows occurrence of DNAPL
     - Installing phase extraction system in ground water wells
     - Separating and collecting DNAPL phase on site; dispose as hazardous waste
   - Treatment of contaminated ground water specific to the chemical composition of the contaminated ground water.

Where will the hazardous wastes be disposed of?

- Hazardous waste should not be disposed of on site. A secured landfill or any other long-term storage of hazardous wastes on the site is inconsistent with residential use and with international standards.

- The disposal should take place off site in appropriate facilities in the developed countries for example Europe unless Indian facilities are available.
- At this time, commercially available options in developed countries including Europe for the final disposal of the hazardous wastes may be limited to conventional combustion techniques such as high temperature incineration. However, the availability and applicability of alternative non-combustion waste destruction technologies deserve further detailed consideration for full-scale implementation off-site.
- Decontaminated materials such as soil and construction materials can be re-used on or off-site after appropriate evaluation.

Are there any risks for the people in the vicinity of the site during the remediation work?

All the remediation work can be carried out without jeopardizing the people in the neighborhood. The emissions of gases and contaminated dust can and must be prevented. Monitoring of contaminant emissions to the surroundings and safety, health and environmental (SHE) management will be part of the project.

What are the costs for the total cleanup?

Based on the evaluation of the currently available data to the team and the team's expertise in remediation, the estimation of the clean up cost based on the preliminary remedial plan is 25-30 million US $ (115-135 Crore Rupees). These numbers may increase as further evaluation of the site dictates. Exact costs depend on the exact amount of soil, wastes and groundwater treated and the time needed for ground water remediation as well as the technologies adopted.

How many years will the cleanup take?

The cleanup of soil and wastes can be carried out in a time of about 4 years:
- Year 1 - immediate measures, site investigation, planning, and tenders.
- Year 2 - disposal or treatment of stockpiles, dismantling of plants and buildings, excavation of contaminated soil.
- Year 3 - Treatment of contaminated soil and other solids
- Year 4 - disposal of wastes and recultivating the site.

The clean up of the groundwater will take many years due to the difficult hydro geological situation and the behavior of the contaminants in the underground.

November 2004 Prof. Harald Burmeier; Dr. Franz Schenker; Dr. Jurgen H. Exner

Prof. Burmeier Ingenieurgesellschaft mbH	**SCHENKER KORNER + PARTNER GmbH**	**JHE Technology Systems, Inc.**
Steinweg 4	Postfach 221	2 Waverly Court
D-30989 Gehrden	CH-6045 Meggen	Alamo, CA 94507
GERMANY	SWITZERLAND	U.S.A
Fon +49 51 08 / 92 17 20	Fon +41-41 378 03 00	Fon +1 (925) 743-9804
Fax +49 51 08 / 92 17 29	Fax +41-41 378 03 03	Fax +1 (925) 743-1870
BIG-H@burmeier-ingenieure.de	franz.schenker@fsgeolog.ch	jexner@earthlink.net