Toxic groundwater – Bhopal's second disaster

The 1984 explosion of the Union Carbide chemical factory in Bhopal, India, was the world's worst industrial accident. Eight to ten thousand people died in the immediate aftermath and many thousands more died in the following years. Twenty five years have now passed and the factory site, right in the heart of Old Bhopal, has never been cleaned up. It continues to release toxic chemicals into Bhopal's soil and groundwater. ***Colin Toogood*** *describes 'Bhopal's second disaster'.*

Just after midnight, on the morning of the 3 December 1984, a Union Carbide India Limited (UCIL) pesticide plant in Bhopal, India, leaked 40 tonnes of the deadly gas methyl isocyanate (MIC) which had been used in the manufacture of the pesticide 'Sevin' (carbaryl). Around half a million people were exposed to the gas that night and the most reliable estimates suggest a death toll of 8-10,000 people within the first 72 hours. Up to 25,000 people are now estimated to have died as a result of their exposure to the MIC gas[1].

Today, more than 120,000 people still suffer from chronic ailments, caused directly by their exposure to MIC, with many thousands more affected by other sources of contamination emanating from the UCIL plant site. The UCIL factory site, and surrounding area, was being used to dump toxic waste and residents of the area were being exposed to toxic chemicals well before the 1984 disaster.

When the factory opened in the 1970s toxic waste was simply dumped throughout the factory site and, when space became limited, beyond its perimeter on land belonging to the elected city government, the Bhopal Municipal Corporation (BMC), in three specially constructed 'solar evaporation ponds' (SEPs). But, in a Union Carbide Corporation internal telex of 25 March 1982, the SEPs were reported to have 'almost emptied' through lining leakage[2].

Although pesticide production in the plant stopped after the disaster, the plant was never fully dismantled, has never been properly cleaned up, and the SEP's were simply abandoned. Chemicals were stored, un-sheltered, on-site for decades and these chemicals have leached through the soil and into the groundwater. The toxic contamination of the soil, and particularly the groundwater, in the surrounding communities, emanating from the on-site waste and the long derelict SEPs, is believed to be the cause of many severe health problems among the residents of these poor communities.

'*It is not a case of 'acute toxicity', but of 'chronic toxicity'. The toxic wastes were dumped by the factory when it was functional between the late Seventies and 1984, and when it was shut after the gas leak. These have contaminated the (ground) water*,' The Centre for Science and Environment, India, director Sunita Narain.

Contamination history

The UCIL factory was built in the city of Bhopal, the rapidly expanding capital of Madhya Pradesh. A site was chosen close to the centre of 'Old Bhopal' right at the heart of the sprawling metropolis. The factory site is surrounded by areas of tightly packed slum housing and is within two kilometres of the main bus and train stations. The promise of work with UCIL, or the trickle-down business around the plant, brought many more families to the area around the factory and these areas remain densely populated despite the factory's present condition.

'*The facility looked as derelict as one would expect, given it has been left to the elements for more than two decades. Despite the presence of full-time security guards, the perimeter fence had been broken in places. A woman was grazing her goats on the overgrown grounds and some shallow hand excavations were identified across the site, where locals had reportedly been digging through buried waste products in the hope of finding suitable building materials for huts.*

A recently secured warehouse contained sacks of raw process chemicals and pesticides, including Sevin, which the plant was commissioned to produce. The site's contaminated status appeared obvious; the exposed soil horizon showed bags of waste and powdered pesticides. Organic odors quickly induced headaches and liquid mercury was seen on the ground. It was said that during production, on-site burial of waste and excess stock was common - it certainly looked as if this were so.'[3]

In past years, groundwater contamination has been documented in the area around the UCIL site, by non-governmental and governmental organisations[4]. Greenpeace conducted three studies (in 1999, 2002 and 2004) and found that groundwater, in the vicinity of the UCIL plant, was highly contaminated with toxic chemicals[5,6,7]. The Madhya Pradesh Pollution Control Board (MPPCB) has monitored the groundwater quality for years and analysed water samples from different communities located close to the UCIL plant. The MPPCB found levels of toxic chemicals greatly exceeding both World Health Organisation (WHO) and National Environmental Protection Agency (EPA) drinking water guideline values. Furthermore, analysis of water samples from seven communities around the UCIL plant showed the presence of several contaminants also exceeding WHO and EPA guidelines[8].

The faulty valve from the MIC plant in the abandoned Union Carbide factory.

Photo: David Graham

The National Environmental Engineering Research Institute (NEERI), Nagpur, India, carried out a study in 1990, at the behest of the State Government of Madhya Pradesh to investigate the pollution caused by the SEP's[9]. The study included the investigation of climatic, geological and hydrogeological (surface waters and groundwater flow) settings of the area on

A boy standing by a hole in the wall surrounding the abandoned and derelict Union Carbide factory in Bhopal. Children play within the grounds despite the dangers from chemical contamination. *Photo: David Graham*

which the SEP is located. Furthermore, an assessment of the water quality and the soil contamination around the SEPs was conducted by testing water and soil samples for several chemicals.

Most of the chemicals found in these studies are chlorinated organic compounds and are known to potentially cause adverse health effects on humans. Besides carbon tetrachloride, chloroform, dichlorobenzenes and trichlorobenzenes, a variety of other chemicals and heavy metals, have been identified. All of these chemicals were used in manufacturing processes at the UCIL pesticide plant.

The contamination today

In 2009, two further studies were released which bring the picture up to date, one by the Bhopal Medical Appeal (BMA), on behalf of the Sambhavna Trust Clinic in Bhopal; and the other by the Pollution Monitoring Laboratory (PML) of the Centre for Science and Environment (CSE), a non-governmental organization based in New Delhi.

BMA study

The BMA study targeted chemicals already identified in previous Greenpeace studies, and specifically focused on the water issues. It looked at the contamination problem but also included a full survey of the water supply situation to the communities including the provision of water, from alternative sources, by the Bhopal Municipal Corporation (BMC).

The Supreme Court of India passed a ruling, in 2004, ordering that a safe water system must be supplied to the affected communities and the BMC was charged with the task of carrying out this ruling. But, the BMA found that the amount of water supplied was insufficient in most of the fifteen communities investigated[10]. Many thousands of residents do not have enough clean water for drinking, washing and cooking and are highly dependent on the water supplied by the BMC. However, the water supply system, where it has been installed by the BMC, is in very poor condition. Plastic water tanks are often broken and are not being cleaned on the inside, promoting algal and microbial growth. Water is supplied by tanker trucks, but is highly irregular and residents are forced to resort to the contaminated supply from hand pumps.

Residents of Atal Ayub Nagar, a slum next to the factory, gather water from a nearby well. The water is heavily contaminated from the factory. It is thought that, as a result, many children have been born with birth defects and many that drink the water have become ill. *Photo: David Graham*

The BMA took samples from one hand pump on two different dates. Testing confirmed the presence of organochlorine compounds in quantities massively exceeding WHO and EPA drinking water guidelines (Table 1). Chloroform concentrations exceeded guideline values by a factor of between four and seven times and carbon tetrachloride between 900 and 2,400 times. The study also found at least 15 other highly toxic chemicals present in the drinking water samples, at levels greatly exceeding the WHO safety guidelines, and further chemicals present for which there are no safe guideline values.

Due to the small sample size the report did not draw conclusions regarding the spatial distribution of the groundwater contamination. However, comparison with previously compiled data indicates that the pollutant load of the groundwater has remained high, and in some cases may have substantially increased throughout the past decade, posing a health threat to residents through chronic exposure.

The BMA report concludes, from the samples taken in one community, that:

'The hand pumps in Atal Ayub Nagar should be shut down immediately as the water is a health hazard for the residents. The water should not even be used for washing as the concentration of solvents present may cause skin problems.'[11]

Table 1. Chemical concentration (µg/L) in water samples from one hand pump on two dates.

Hand Pump AA1 (Atal Ayub Nagar)	chloroform	carbon tetrachloride	1,2,3-trichlorobenzene
UK lab (July 2009)	266	4880	-
Swiss lab (May 2008)	148	1790	17
WHO guidelines	300	2	20
EPA guidelines	70	5	-

CSE study

The CSE studied the chemistry of the processes used for producing pesticides, at the UCIL site, and selected four groups of chemicals for testing in soil and water samples. It tested for chlorinated benzene compounds: 1,2 dichlorobenzene; 1,3 dichlorobenzene; 1,4 dichlorobenzene; and 1,2,3 trichlorobenzene. It also tested for: organochlorine pesticides alpha, beta, gamma and delta hexachlorocyclohexane (HCH); five heavy metals lead, cadmium, chromium, mercury, arsenic; and the two main products of UCIL carbaryl (Sevin) and aldicarb (Temik) – both largely produced for cotton cropping systems.

The CSE tested one stored waste sample, six soil samples and one surface water sample from within the UCIL site and one soil sample from the SEPs. The tests showed that the land within the UCIL factory and around the SEP's is highly contaminated with pesticides, chlorinated benzenes and heavy metals[12].

The CSE also tested groundwater samples taken from various communities around the UCIL site. It found that the concentration of pesticides in all water samples were between 1.1 to 59.3 times the only mandatory water standard in India, fixed by the Bureau of Indian Standards (IS:14543). The average concentration in all groundwater samples tested, including those up to 3.5km from the factory site, was 0.006 ppm, which is 12 times the standard.

The CSE also found that:

- the waste stored within the UCIL premises contained all chlorinated benzene compounds and all organochlorine pesticides tested for by the PML. The total pesticide concentration in the waste sample was as high as 9867 ppm.
- the soil samples contained all the chlorinated benzene compounds and organochlorine pesticides tested for. It also had four out of five heavy metal tested by PML.

● the profile of chemicals found within the UCIL factory and in the waste disposal site of UCIL matches the chemicals found in the groundwater sample in the colonies outside the factory premises. There is no other source of these chlorinated benzene compounds and pesticides than UCIL. The topography of the area also points towards contamination of the groundwater due to the UCIL. The plant is located at a slightly higher altitude than the residential colonies.
● finding carbamate pesticides in groundwater 25 years since the UCIL plant shut down, provides a strong indication that the plant is acting as a continuous source of groundwater contamination[13].

A summary of the health effects, on the human body, of the various chemicals and heavy metals found in BMA/CSE tests, can be found in BMA[14], CSE[15] and Greenpeace[16] reports.

The politics of clean up

The Dow Chemical Company purchased Union Carbide in 2001, inheriting both the assets, and liabilities, of the Union Carbide Corporation UCC). UCC were the controlling shareholder, with a 50.9% stake, of UCIL but Dow refuse to accept any responsibility for the disaster in Bhopal. Dow have repeatedly stated, in the media and elsewhere, that the Union Carbide Corporation (UCC) and Union Carbide India Limited (UCIL) settled their liability for the gas release tragedy with the Government of India in 1989 with a payment of US$470 million. Whilst this is true, this settlement does not, and never has, covered any liabilities arising from subsequent and continued contamination or the contamination of the groundwater.

Warren Anderson, chairman of UCC at the time of the disaster and, along with UCC, the prime accused in the criminal case of culpable homicide, lives in upstate New York and has never been punished. The case against him is still pending in a lower court in Bhopal. Documents obtained from the US State Department under the Freedom of Information Act, are most revealing. A letter to the State Department review authority Archie M Bolster (dated 24 July, 2003), from a US industry representative, stated, *'the request to extradite Warren Anderson should be rejected. No issue has greater potential to destroy US business leaders' confidence in India than the handling of the Warren Anderson case.*' In August 2009, when the Chief Judicial Magistrate issued a second non-bailable warrant against Warren Anderson, the people of Bhopal spilled on to the streets to celebrate.

Children play cricket within the grounds of the abandoned Union Carbide factory despite the dangers from chemical contamination.
Photo: David Graham

Women collecting water from a standpipe in the street of Bhopal. These deliver the water brought in by tanker lorries by the Bhopal Municipal Corporation.
Photo: David Graham

'*Union Carbide and Dow were allowed to get away with it because of the international legal structures that protect multinationals from liability. Union Carbide sold its Indian subsidiary and pulled out of India. Warren Anderson, the Union Carbide chief executive at the time of the gas leak, lives in luxurious exile in the Hamptons, even though there's an international arrest warrant out for him for culpable homicide. The Indian government has yet to pursue an extradition request. Imagine if an Indian chief executive had jumped bail for causing an industrial disaster that killed tens of thousands of Americans. What are the chances he'd be sunning himself in Goa?*' writes Suketu Mehta[17].

Despite Dow's continuing refusal to accept any responsibility for cleaning up the site there is a belief that India's government wants to end the current impasse in Bhopal, partly for humanitarian reasons but perhaps also to allow Dow to expand investments currently curtailed, and under attack, by activists. Dow had been asked by the Indian Government to deposit a sum of US$22 million against remediation costs, pending a hearing in the Madhya Pradesh High Court. But, in November 2006, Dow Chairman, Andrew Liveris, wrote to Ronen Sen, Indian Ambassador to the US suggesting that this position was *'adverse to the company'*. He requested the Government of India to withdraw the application in return for '*economic growth in India, including key foreign investments that will promote job creation*'[18].

For their part, the campaigners have appealed to the Indian Government in Delhi to establish an 'empowered commission' to co-ordinate progress in the legal case and the clean-up. The Commission would be empowered to allocate resources to different rehabilitation schemes, or research projects, and could issue tenders, and engage other Central or State Government agencies, without recourse back to Central Government. But the Madhya Pradesh State Government is resisting Delhi's attempts to set up any such commission despite the Central Government announcing the establishment of such a commission in August 2008.

Satinath Sarangi, managing trustee of the Sambhavna Clinic, which treats survivors in Bhopal, believes that part of the problem is Dow's refusal to formally accept responsibility for what Union Carbide allowed to happen and that a 'compromise could be reached' if Dow made provision for health damages and monitoring of patients, and agreed to clean up the site and surrounding areas, which it is still resisting. 'That would be some sort of compromise that we would consider', he said[19].

Where now?

The Central Pollution Control Board (CPCB) of the Government of India, has also been testing the groundwater and, although their report is not yet officially published (despite being expected for some months) it is believed that their test results largely concur with the BMA and CSE reports. However, CPCP Chairman SP Gautum said *'I am not aware if the results of the research conducted on the collected*

Bhopal – 25 years and exposure continues

A plan to open the site of the Bhopal disaster for 15 days was labelled a 'dangerous publicity stunt' by the gas tragedy survivors, who saw this as an attempt to overshadow their campaign for justice on the 25th anniversary of the disaster.

The two reports by the BMA and CSE, released on 1 December 2009, helped to counteract this bizarre proposal of Madhya Pradesh Minister Babulal Gaur. Gaur, the Bhopal Gas Tragedy Relief and Rehabilitation Minister, announced that the 'The plant is being opened to help people get rid of the apprehension and misconception that the chemical wastes lying in the factory are still harmful and are polluting the ground water of the nearby localities.'

Gaur based his conclusion that the chemical wastes on site are not harmful on a 2008 report by the Defence Research and Development Establishment (DRDE)[1], Ministry of Defence, Gwalior. DRDE tested the acute oral toxicity of samples from unspecified locations within the factory site. These consisted of: excavated waste, lime sludge, naphthol tar, reactor residue, semi-processed pesticide and Sevin tar. DRDE concluded the residues had 'very low mammalian toxicity' and that a human would have to eat as much as 200 gms of the waste to die from it.

The problem in Bhopal is not one of acute toxicity which is unlikely to occur[2]. As explained in this article, the problem is one of chronic toxicity whereby gradual exposure to these chemicals, especially from contaminated drinking water, is linked to disease, birth defects and cancers. So it is not the LD_{50} (dose which will kill half of the animals which consume it) that needs to be measured but the acceptable daily intake (ADI). When measuring ADI these pesticides have high chronic toxicity[3] – in fact, we should not be exposed to them at all.

1. DRDE Report. Acute Oral Toxicity of Samples of Stored Toxic Wastes at the Former UCIL Plant Site at Bhopal in rats. October, 2008. http://www.indiaenvironmentportal.org.in/files/DRDE-October2008.pdf
2. The exception to this being the numerous children, in affected communities, suffering from Pica, a condition where there is an appetite for non-nutritious substances.
3. The ADI of carbaryl (Sevin) is 0-0.003 mg/kg body weight. The ADI for lindane is 0-008 mg/kg body weight; ADI for aldicarb (Temik) is 0-005 mg/kg body weight.

samples are out,' But, according to *The Hindu* (newspaper): '*Reliable sources, on condition of anonymity, said that since the CPCB findings confirm contamination, it intends to sit on it or it would cause embarrassment to the Union Government and the Ministry of Environment and Forests, which has been denying contamination.*'[20]

By any credible reckoning the groundwater contamination in Bhopal has to be accepted as fact and the forthcoming CPCP report may prove something of a litmus test. But, even if the contamination is accepted, the question still remains 'Who will pay for the clean up?' Dow, despite purchasing Union Carbide, along with all of its assets and liabilities, still refuses to acknowledge responsibility and there is plenty of evidence of political pressure to dilute its liabilities.

'This cannot be acceptable ... The toxins we have found in the factory are related to the production process of the plant. It is clear that UCIL was dumping its waste – of chemicals and pesticides – in the factory compound over the years it operated the factory. Dow must be held responsible. "Its own annual report shows that it has taken on the liability of Union Carbide in the case of asbestos exposure in the US. Why is it denying this responsibility in India?' CSE, India, director Sunita Narain.

Practically speaking, the recent reports are extremely worrying. The assumption, up to now, has been that perhaps 30,000 people are affected by the water contamination in Bhopal. But it may be a far greater problem. Numbers of affected people have largely been based on the data of tests that are anything up to a decade old. The new reports show two very interesting things:

- the contamination levels are increasing over time. When a comparative analysis is made of test results from the same borehole, which was possible with the BMA tests, (one particular well was tested twice by the BMA and once by the BBC over a period of nearly 18 months) the ingress of toxins appears to be increasing over time;
- the contamination has gone much further into the aquifer than anybody has previously estimated. This assumption is based on two pieces of evidence. Firstly, that the results of the CSE tests showed the greatest pesticide contamination, in ground water samples, at Shiv Nagar a distance of 3.5km to the North East of the UCIL site. Analysis of the aquifer, by NEERI, suggested that the plume would flow at a rate of between 2-300 metres per year and the report, along with anecdotal evidence, seems to suggest the plume travelling in a North to North-easterly direction. Taking this into account it is not surprising that the toxic plume has reached Shiv Nagar but what is more worrying is the concentrations found which suggest that the plume has travelled well beyond Shiv Nagar and much further than any previous estimates suggest. More worryingly still is the fact that the CSE report also found extremely high levels of pesticides in the ground water at New Arif Nagar which is directly North-West of the UCIL site.

Taking both of these facts into consideration seems to suggest that the groundwater contamination is in fact much wider spread than previously thought. On that basis the number of people being affected by this toxic supply must be massively in excess of the previous estimate of 30,000.

This toxic contamination of the ground water is Bhopal's 'Second Disaster'.

Information about the Bhopal Medical Appeal and its activities to support health care in Bhopal can be found on www.bhopal.org

References
1. These numbers are open to debate but the most generally accepted figures are these, as endorsed by Amnesty International, BMA and others.
2. J Jackson and M McLoughlin, Bhopal Disaster: Still Waiting For The Clean Up. ENDS Report 406, November 2008, pp32-35.
2. Ibid.
4. A Häberli and C Toogood, Analysis of Chemical Contaminants in Groundwater and Assessment of the Qualitative and Quantitative Drinking Water Supply Situation in the Communities Surrounding Union Carbide India Ltd. (UCIL) Plant Site in Bhopal. The Bhopal Medical Appeal, for the Sambhavna Trust Clinic, Bhopal. http://water.bhopal.org/
5. Labunska I, Stephenson A, Brigden K, Stringer R, Santillo D and Johnston PA, The Bhopal Legacy: Toxic contaminants at the former Union Carbide factory site, Bhopal, India: 15 years after the Bhopal accident. 1999. Greenpeace Research Laboratories, Department of Biological Sciences, University of Exeter, Exeter, UK.
6. Stringer R, Labunska I, Brigden K and Santillo D, Chemical Stockpiles at Union Carbide India Limited in Bhopal: an investigation, 2002. Greenpeace Research Laboratories.
7. Labunska I and Santillo D, High levels of chlorinated organic compounds, including tetrachloromethane, in water from well adjacent to former Union Carbide India Ltd (UCIL) pesticide plant, Bhopal (India), 2004. Greenpeace Research Laboratories.
8. Srishti, Toxic Present – Toxic Future: A Report on Human and Environmental Chemical Contamination around the Bhopal disaster site. 2002. H-2, Jangpura Extension, New Delhi – 110 014.
9. National Environmental Engineering Research Institute, Assessment of pollution damage due to Solar Evaporation Ponds at UCIL, Bhopal. 1990. NEERI, Nagpur – 440 020, Madhya Pradesh Pradushan Nirawan Mandal, Bhopal.
10. Op cit 4.
11. Op cit 4.
12. Johnson S, Sahu R, Jadon N and Duca C. Contamination of soil and water inside and outside the Union Carbide India Limited, Bhopal. Centre For Science and Environment, December 2009.
13. Ibid.
14. Op cit 4.
15. Op cit 11.
16. Op cit 5.
17. Suketu Mehta, A Cloud Still Hangs Over Bhopal, New York Times, 2 December, 2009.
18. N Bhalla. Dow Chemicals avoiding Bhopal tragedy-activists, Reuters 9 April, 2007, www.reuters.com/article/idUSSP226658
19. J Elliott, Riding The Elephant Blog, 1 December, 2009,http://ridingtheelephant.wordpress.com/
20. Hindu, 7 February, 2010.

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