Original Article

MIC LEAK DISASTER AND ENVIRONMENTAL CONTAMINATION: TIME TO ACT NOW

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Financial Support: None declared

Conflict of interest: None declared

How to cite this article:
Mishra B, Banerjee N. MIC Leak Disaster and Environmental Contamination: Time to Act Now. Natl J Community Med 2014; 5(1): 13-20.

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Date of Submission: 21-09-13

Date of Acceptance: 10-01-14

Date of Publication: 31-3-14

ABSTRACT

Back ground: More than a quarter century has passed since Methyl Isocyanate disaster took place at Union Carbide's Sevin manufacturing plant at Bhopal on the night of 2nd /3rd December 1984. Mixture of toxic gases settled down on densely populated old city of Bhopal affecting human beings, animals, plants and even microflora. The stored stockpiles and the products of reactions contaminated air, water, soil and human as well as animal bodies.

Methods and Procedures: field visit; monthly /six monthly and annually were made to have first hand information on the affected area and the localities surrounding it. Extensive secondary data review was done to understand the genesis, quantum and the potential of the contaminants to harm the environment and the human health.

Results: It was found that the air was clean by 6th December 1984 and threat to environment by stored MIC was removed by 22nd December 1984. Soil was evaluated and observed that the potential to cause acute toxicity was at minimal by 2002. In 2013 water from local tube wells was found contaminated with inorganic Lead and HCH (>permissible limit) and HCH γ under permissible limit and it is recommended to be used for only non internal consumption purposes. Soil which at present is the main source of future contamination needs immediate remediation.

Conclusion: Fear of contamination and resultant ill health is so far unsubstantiated. However, further study should be conducted to link toxicant present in water/soil, pathways to reach food chain and ultimately human body and with their present health status. Soil remediation should be under taken on war footing.

Key words: MIC Disaster, Toxic contamination HCH, Atmospheric inversion, Remediation

INTRODUCTION

Bhopal (longitude-77.35^0 east, latitude- 23.25^0 north and altitude - 500-600 meters above sea level) capital city of Madhya Pradesh, India suffered a major industrial disaster following toxic gas/s leak from a Union Carbide factory on the night of 2nd /3rd December 1984.

Union Carbide India Ltd. factory is situated in the northern part of the old city. The Union Carbide factory was installed in 1969 on about 68 acres of land near old city to manufacture pesticide Carbaryl, sold under trade name Sevin. Manufacturing process of Sevin required Methyl Isocyanate (MIC) gas as raw product. MIC was initially imported from USA and later since 1979, plant begin to manufacture MIC locally. The MIC thus produced was stored in any two of the three storage tanks (no.– E610, E619 and E611) under refrigeration and high purity Nitrogen pressure[1].

On the night of 2nd/3rd December Tank no. E 610 contained 42[1]-45[2]tones of MIC. The composition of MIC in tank was similar to the MIC stored in tank E611 (MIC-99.85, Phosgene-0.32, Chloroform- 0.334, hydrolysable chlorides-0.130, all in %W/W and trace metals like Iron-4.1, Zinc 3.7,Chromium-1.0, Sodium-0.9,Copper-0.3,Nickel 0.2 and Magnesium 0.03(all in ppm) (sample taken on 20.12.84)[3].

On the night of 2/3rd December 1984, following various management, systems, logistics and human failures outside the purview of this paper, an uncontrolled run away exothermic reaction began with entry of about 500 kg. of water in to tank no. 610E. Later examination of the tank residue and retrospective analysis of the condition for formation of the residue and total energy balance indicated that temperature in the tank must have reached to 250^{0}C, while mechanical examination of the tank indicated that the temperature in tank must have shot up to 200-350^{0}C[4]. This reaction

in presence of Metallic catalysts consumed 12087 kg of MIC (of the stored 42 tons) and 595 kg of Chloroform[5]. Theoretically, exothermic reaction produced products of reaction by two routes. Major route reaction produced HCN, CO, H_2, while minor route reaction produced N,N'-dimethy carbo-di-imide and CO_2[6]. Following the accident three groups of chemicals were found posing threats to human health; a) the stockpile of remaining inventory brought in the factory for making Sevin, b) the product of reaction gases spilled over the population of the Bhopal and c) the solid products of reaction in the tank residue. All the three groups were potentially toxic and were capable of harming the environment, air, soil, water and the human health.

This paper thus is an attempt to revisit the holocaust intellectually and understand it in simpler terms of cause, quantum and severity with which it contaminated environment and human bodies vis a vis the process of recovery. This paper is also a humble attempt to alleviate the fears, some of them unfounded and explain the sufferers that the worst is over and the life ahead will be normal, if not for all but at least for majority of them.

OBJECTIVES

The objectives were to study the immediate, long term future (after 29 years) potential of contamination caused by the MIC leak disaster and to study the process of recovery alongwith the future challenges.

METHODOLOGY

Method: Field visits and secondary data review: Field visits to the study area were made during 2007-2008 for initially six months on monthly basis and later on six monthly basis for evaluation of the study area including the colonies around the Union Carbide plant and the solar evaporation ponds. Later since 2008 the area was visited annually just to review any new development in concerned area of interest.A large body of data has been gathered by various agencies, which has been adequately reviewed and interpreted while referring in this study.

OBSERVATIONS

Field visits: The area was visited by authors during 2007-08 and later till date and studied in detail through visits and extensive review of literature as below:

The Area: As stated above the Union carbide factory was built over an area of 30hectares of land situated in northern part of the old city. Originally the factory and the Solar Evaporation Ponds were built on a barren land area called Kali Pared. And as soon as factory started functioning, it got surrounded by the slums and hutment busties roughly 14-19 in number.

The factory/area stands on black cotton soil up to 2.0 meter and presence of clay mostly plastic in nature with Kankar below up to depth of 20-30 meters. This plastic clayey soil has more than 45% of the clay content. This clayey soil is highly impermeable and (Toxicant) would travel approximately at the rate of 36cm/year at the rate of $1X10^{-5}$ cm/Sec. It would take 23 years for the contaminants to reach the ground water table provided the leachets do not find a channel to migrate at faster rate[7]This factory, for sake of clarity can be divide in two parts divided by a railway line: one the manufacturing unit (16 hectares and second about 800 meters away three Solar Evaporation Ponds (with double polyethylene sheets at the base and extending to brims to prevent leaching and contamination spreading to surrounding areas) in 14 hectares, to process the wastewater (Acid waste, Processed sewer waste, Sanitary waste and sullage)generated in factory[8]before it is drained in to patra nala[1]. The factory is situated at the level 24 meters below the upper lake and 15 meters below the lower lake. General direction of hydrological flow was in the direction north- north east[9].

Retrospectively in 1990 it was observed that there was no substantial variation in crop yield and people residing in nearby hutments did not report any dour problem in last five year[10]. In 1991 a study to assess the effect of MIC leak on vegetation cover in Bhopal city and surroundings it was found that in general there was little or no change in permanent vegetation cover such as forest, plantations, orchards, built up land dominated by trees covers park gardens show little or no change. And visual interpretations of satellite data do not indicate any change in vegetation due to leakage of MIC gas[11].

Since 2007 and till date the affected colonies were found full of life giving impression of a lively slum with full of life and the people living here, were always busy with their daily chores of life: operating Madrasa, playing chess, enjoying bath in piped water supply etc. However, most disturbing elements of human activities, investigators observed is that these activities were leading to direct damage to the double layer of the film (within which the toxic soil is contained either from the land fill or the bund of the solar evaporation pond). This soil was being collected by the children for some use at home[12]. The govt. agencies are supplying water from the distant area and they are developing over hand tanks and pipelines. However, by and large the area is not fit for any type of human habitation.

The factory premises and the localities surrounding the factory are often considered as contaminated hence, it becomes pertinent to understand the genesis and quantum (to begin with and at the present) and impact potential of the so called contamination in reference to agent environment and host model:

1. The Agent/s

Following disaster three categories of chemicals were seem to be present in and around the Union carbide premises: these chemicals included the a). Remaining

raw stockpile accumulated during the 15 year of operation, b) the gaseous products including Cyanide of runaway reaction on 2nd/ 3rd December 1984 and c) the solid products of runaway reaction.

a. **Solid stockpile and accumulated toxicants during the 15 year of operation:**Between the periods of 15 years (1969-1984) a number of chemicals[13] were brought in during the operational phase of the factory. These chemicals were capable of polluting air/ soil/water (Table 1)- The Solar Evaporation ponds were examined in 1990 and it was found that the wastewater and the pond water contained Chlorides and Sulphates of Calcium and Sodium. Lead and Cadmium was found either in very low concentration or below detectable limits. Carbaryl, alpha Naphthol and methylamine were not present. Chloroform and Carbon Tetrachloride were absent in Pond water[7/8].In 2002 Greenpeace reported that until 2002 large stockpile of chemicals and unknown waste were present onUCIL plant site. The stockpiles were shown to contain toxic and persistent chemicals often contained inadequately,although many chemicals were present at concentration too low to show acute toxicity[14].In 2005 MP Pollution Control Board recovered and stored waste as Sevin residue (11 mt), semi processed pesticide (142.80 mt) contaminated soil (165 mt) and lime sludge(39.6mt)[15].

b. **Gaseous products including Cyanide**: on were assumed to be MIC—28-tonnes. Carbon Di Oxide 1.25 tonnes, Ammonia -80kg. and Methyl Chloride, Carbon Tetra Chloride, some Akylamines in very small amount[16].Besides above cyanide production needs special mention as there were divergent views on cyanide formation during the accident. One group believed that cyanide was formed while other categorically denied this.

The theory of cyanide formation is largely based on an observation made by Blake and Ijadi Maghsoodi in 1981/82 that on experimental pyrolysis at 427-570^{0}C MIC leads to generation of HCN, CO and H_2through major route andN,N'-dimethylcarbo-di-imide and CO_2through minor route[17]. But was it generated at 350^{0}C[4]the rise of temperature likely to have reached during reaction in tank. It was found that in presence of Chloroform Hydrogen Cyanide did not form[5]and further experimentation with products of reaction namely MICT, DMI, DION, DMU and TMB heated up to 300^{0}C did not yield Cyanide even in absence of chloroform. HoweverMIC prepared from Sodium Azide and Acetyl Chloride, when heated in sealed glass tube with water and ferric chloride did produce small amount of Hydrogen Cyanide[16]. Similarly Cyanide formation in small amount at lower temperature was further confirmed. On exposure to +200 °CMIC breaks down and yields 3% hydrogen cyanide (HCN) [18]and on experimental pyrolysis at 350^{0}CMIC produced 4.7% HCN[19].So, it is likely that MIC partially cracked at high temperature and may have produced HCN, CO, and N_2 or CO_2, but by how much is uncertain[20]. Lastly five years later aqueous extract of tank residue material was analyzed for free cyanide and clear indication of its presence on the day of disaster was found[21].

c. **Tank Residue Chemicals**: solids produced as result of runaway exothermic reaction remained in the tank no E 610 and labeled as tank residue. In 1985, these were identified and reported[3,22,23,24](Table 1).

The composition of the gas cloud: On the basis of the available information from the various sources (cited above) the gas cloud which escaped through the 33 meter high vent gas scrubber may have contained the chemicals mentioned in table 1.contained many gases and their adducts. The adducts formation has also been noticed by other workers[25,26].

Table 1: Toxic Contaminants

Potential of Contamination	Chemicals, Stockpile[13] (all in Metric tons)
Those capable of polluting air	Methylene Chloride (1000, Methanol (50), Carbon tetrachloride (500), Chloroform (300), Tri methylamine (50), Mono methylamine (25), Chlorine (20), Phosgene (5), Naphthalene (50),
Capable of polluting air and soil	Hydrochloric acid (50), Chloro sulphonic acid (50), Alpha Naphthol (50),
Those capable of polluting water and soil	Mercury (1) and Chemical waste Tar (50)
Those capable of polluting air water and soil	Ortho-dichlorobenzene (500), Chloro benzyl chloride (10), Mono chloro toluene (10), Toluene (20), Aldicarb (2), Carbaryl (50), Benzene Hexa chloride (5) and Methyl Iso Cyanate (5)
Products of reaction (TRC)[3, 23, 24] (all in Kg.)	
Solids Capable of polluting soil and water	Methyl Isocynate trimer (6964), Dimethyl Isocynurate (2675), Dimethyl urea (161), Trimethyl urea (191), Dion ((391), Trimethyl biurate (117), Tetramethyl biurate (traces), Monomethyl amine (129 , Dimethyl amine (246), Trimethyl amine (423), Chlorides (540) and Metallic ions of Fe-1275,Cr-260-,Ni-95, ,Na-60, Mg-3) (all in ppm). Chloroform, Cyanide, spiro compound and 11 unknown compounds (M/z 142-28)
Gases capable of polluting air	MIC, HCN and HCN adducts with MIC droplets[6] (2MIC~HCN and MIC~HCN), Carbon Di Oxide, Carbon Mono Oxide, Hydrogen, Ammonia, Methyl Chloride, Carbon Tetra Chloride, some Alkylamines (amount cited above)and N,N'-dimethyl carbo-di-imide

Environment

On the night of 2nd /3rd December temperature was about 17^{0}C, relative humidity about 60% and wind speed 10-11km/hr. flowing in Northeasterly direction[2]according to some other accountsinitially it was north westerly[20]. The mixture of hot gases mentioned above escaped in to atmosphere and got condensed in outside cold air and due to atmospheric inversion phenomenon settled down slowly on the ground. This settled mist or cloud of toxic gas/es evaporated and spread in the atmosphere gradually due to low wind velocity between 23.30 PM on 2nd December 1984 and 3 AM on 3rd December 1984 over the densely populated old city situated on comparatively planes[1] and surrounded by the high hillocks namely Idgah hills, Shymala hills and Birla hills on three sides.[2]The airspace in affected area was filled with slowly drifting gas cloud containing chemicals cited above.

Air

It is known that Methyl Isocyanate on coming in contact with water rapidly (minutes to a few hours) gets converted in to Methylamine (MA) (if water in excess) or Dimethyl Urate (DMU) and Trimethyl Urate (TMU) (if water is scanty).[2] Following disaster first evaluation of environment was done on 5-6th December 1984 for presence of Isocyanates or related materials in air water or surfaces. The tests carried out did not show presence of MIC in environment.[1] However Urea a product of MIC breakdown was found in excess of normal inside the plant and affected area till 5-6th December 1984[2]. Later after removal of 21 Tones MIC from tank no 611 and 1 tone MIC from tank no. 619 during operation faith (lasting almost seven days:16-22ndDecember 1984), noMIC was left in the factory premises/environment.[1] Presence of cyanide in air was noticed in close vicinity of the plant only till fifth day and indicator test tubes confirmed absence of NO, Cl_2 (<0.2ppm) and CO(<5ppm) by same date.[2] In summary one can say that in absence of any fresh source of contamination the air of the affected area was clear of CO, NO_2, Cl_2 , CO_2 and MIC after 6th and 21st December 1984.

The Soil

Effect of MIC leak was also evaluated on soil. The pH of the soil was found to be in the range of 7.9-8.6, the organic carbon content was 0.5-3.3, the total nitrogen content 0.3-0.6 with a C/N ratio of 11-5.27. The investigators concluded that no distinct trait was found to arrive at any conclusion in respect to soil damage on immediate basis[27]. However, the leftover chemicals and products of reaction in form of tank residuecited under agents a and c remained unattended immediately following disaster were feared to contaminate the soil.

Greenpeace in 1999, took soil samples from the plant sites and from the adjacent communities. On analysis it found that the plant sites were contaminated with heavy metals and chlorinated organic compounds. Elevated levels of mercury, chromium, copper, nickel and organochlorines as hexachloroethene, hexachlorobutadiene, exachlorocyclohexane isomers, DDT and numerous chlorinated benzenes were reported. SEP sites were found less contaminated[28].In 2002, Greenpeace found that toxic substances were present but their concentration was too low to show acute toxicity[14].Sristhi in 2002 analyzed 14 soil samples,(5 from plant sites and 9 from residential areas and found them contaminated with chloroform, HCH Isomers and VOCs Nickel, mercury and chromium[29].

National Environmental Engineering Research Institute (NEERI) conducted a series of studies on the issue of contamination and reported in 2010 that of the nine sites three (I, III and V) were contaminated by BHC, aldicarb, carbaryl, α-naphthol and mercury up to the depth of about 2 meter except at one dump (Site III) that could be deeper (4-8m) and the total area of contamination was calculated to be 28 hectares up to depth of two meters and the quantum of the soil which needs remediation thus comes to 11,00,000 mt.[15].

In 2012, surface and sub surface(up to depth of 30 cm) soil was reanalyzed for its toxic contents and it is reported that of the 24 sites only one site was near the formulation plant was found contaminated with high level of HCH isomers. Andexcept for this site by and large NEERI and CSIR-IITR report are in agreement[30].

The waters

The Water collected from affected area was analyzed for cyanide and found free of cyanide by 5-6 December[2].

Water samples between 1985- 2006 were tested by NEERIin 1985, 1989, 1990. 1992, 1997 and 2010, By M.P. Pollution Control Board 1996, 1998, 1999, 2004, 2005, Greenpeace in 1999, National Institute of Occupational Health in 2005 and lake conservation Authority in 2006. Of the 13 occasions at least six times this water was found as of drinking quality[31].

Sristhi in 2002 analyzed 11 water samples, and found them contaminated with Dichloromethene, Chloroform and Nickel[29].In 2006 Lake Conservation Authority tested the water being supplied to the affected area community and found that the water brought form 10 Km outside the affected area contaminated with high coliform counts, hence not suitable for drinking[31].

NEERI in 2010 observed that ground water from the bore wellsconstructed by NGRI within UCIL premises and the existing wells around UCIL premises indicated that ground water in general is not contaminated due to seepage of contaminants from UCIL dumps. And isolated contamination of 5 bore wells in terms of pesticide cannot be attributed to UCIL dumps[15].

Lastly in 2013 CSIR-Indian Institute of Toxicology Research found the presence of inorganicLead Above the permissible limits for drinking water-(BIS IS 10500:2012) in samples collected from outside the UCIL premises have no relation with past UCIL activi-

ties. Presence of organics like HCH (a,β,δ) in more than permissible limits and HCH γ in under permissible limits could be due to past UCIL activities as well as due to usage of HCH in other agricultural /Horticultural practices in surrounding areas. And in view of above the water can be used for other purposes like cleaning bathing and gardening etc.[30].

2. Host

Evidences of contamination by constituents of gas cloud/tank residue in postmortem

Cyanide: Presence of cyanide was confirmed in blood of toxic gas exposed dead victims with help of Drager tubes on 8th December 1984[32]. Cyanide levels study in cadaveric blood among 43 affected and 31 control was conducted and it was found that the blood cyanide levels among exposed were ranging between 60-360mg% (av- 150mg%) against the range of 10-50 mg% (av-25mg%) among contol[33]and further presence of trapped cyanide in lungs too was confirmed[21].

MIC: The carbamoylation of the postmortem blood and tissue was demonstrated in 1984 all the 7 blood samples were positive for carbamoylation while of the 35 tissue samples 17 were positive for same. In 1985 of the 9 blood samples 4 were positive while of the 18 tissue tested 4 were found positive for carbamoylation[33].

Breakdown product of MIC: Methyl Amine smelling like rotten fish was found in one autopsy done on 20th December 1984[34].

Tank residue: Autopsies and blood samples collected from cadavers in 1984-85 showed presence of MICT, DMIT, 2,4- Dione, compound m/z279 and compound m/z 269[24].

Evidences of contamination by constituents of gas cloud/tank residue in hosts/human animals:

Before embarking to understand the mechanism of pathogenesis one must understand that though MIC was stored in tank no. 610E but the released products of reaction were a mixture of many compounds cited above. Secondly, Union Carbide officials' stand that MIC was nothing more than a potent tear gas and thirdly that MIC does not cross the alveolar–capillary barrier needed reexamination.

Presence of HCN: Presence of cyanide like poisoning was suspected even while conducting early autopsies but confirmation of arterializations of venous blood drawn from hospitalized cases on 5th-6th December 1984[35] was one important breakthrough in this direction. Blood and tissue cyanide levels were measured among exposed and compared with control. It was found that HCN levels of blood of exposed were more than double compared with control group indicating some cyanide toxicity[33].Indirect evidences on presence of cyanide in toxic gas exposed survivors were confirmed in January 1985. In this study of the 14 gas exposed symptomatic cases, 10 cases showed 50% increase in urinary thiocyanate excretion when given intravenous injection of thiosulphate[36].

Presence of MIC: Demonstration of "N carbamoylated end-terminal valine residue of Hemoglobin" in the blood samples of cadavers and survivors confirmed presence of MIC in body. Initially a reduction of free amino groups of hemoglobin was demonstrated by TNBS reaction; later chromatographic studies confirmed MIC binding with end-terminal valine residue. One and a half month following disaster vMVH was demonstrated in 19 out of 60 exposed persons and 7 out of 11 cord blood samples. These observations conformed that MIC not only crossed alveolar- capillary barrier but had also crossed placental barrier. Carbamoylation of terminal valine residue of myoglobin could explain the extreme muscle weakness[37].

Presence of Carbon Mono Oxide: The gas exposed living in railway colony region were evaluated for respiratory changes within 7-90 days post exposure. It was found that of the 70 evaluated 94.3 % had raised COHb and among 11.4 % the level was higher than 6%. The level declined significantly after three months. In same study MetHb was measured in 111 subjects and in 83% it was raised but declined after three months[38]. Carbon mono oxide was detected in blood of suffering animals as well[27]. Similar observation of presence of CO in form of carboxyhemoglobin in blood of exposed animals was noted by other group as well[39].

Presence of MIC metabolites in food meat and breast milk: It is claimed that MIC is not known to accumulate in food chain[40].However, milk and meat samples from goats and buffaloes were shown to have product of MIC breakdown i.e. Methyl Amin and Dimethyl urea. Buffalo and goat meat revealed changes in lipid metabolism. Methyl Amine and Dimethyl urea residue were found in milk and meat of exposed animals. By November 1985 goat and buffalo meat samples were found to be of normal quality. Milk samples from exposed animals even after a year were below PFA standards[10].

Sristhi in 2002 analyzed unknown number of food samples and found them contaminated with chloroform Nickel chromium and mercury. It also analyzed 11 breast milk samples and found them contaminated with Chloroform, HCH isomers, VOCs, Nickel, mercury and lead[29].

DISCUSSION

The Bhopal MIC leak disaster the world's biggest chemical disaster besides killing thousands and forcing long time sufferings to a very big population also created fear in the minds of public and concerned groups that MIC leak in end 1984 led to environmental contamination. It is only half truth. Contamination of soil and water (?) began in 1969 itself due to storage, manufacturing and indiscriminate dumping[15] of the chemicals in the premises. And resultant products of

exothermic reaction following MIC leak contributed further to preexisting contamination. One can say that MIC leak disaster was a timely warning to prevent contamination though at a very high cost.

The issue of air pollution when examined and deduced from the various accounts narrated by the local residents and sufferers, it becomes clear that the air space surrounding the factory and the affected city got cleared of the deadly combination of gases by 4-4.30 am following dilution and dispersion of the gases in the early hours of December the third 1984 itself. Central Water and Air Pollution Control Board, a government agency did not find presence of MIC or Urea or other Isocyanate related material, CN, NO, Cl_2, CO, CO_2 and NO_2in air, water or surfaces beyond 6th December 1984. By 22nd December 1984 Bhopal was free of the remaining MIC as well.

There is no disagreement to the issue that the soil contamination began with the beginning of the factory itself in 1969. However, it is the quantum and potential of the toxicant which are the point of debate. On the morning of 3rd December 1984 the factory area was said to be littered with 22 chemicals (cited above).However, at this juncture one must realize that the chemicals mentioned in the exhaustive list of 22 chemicals were definitely not present in the amount mentioned against their names on the night of accident as most of them were consumed while manufacturing the pesticides over last 15years (1969-1984). To support the statement example of Methyl Isocyanate would be sufficient. It is said that over the 15 years 5mt of MIC was brought in or produced but on the night of accident only 64 tonnes was present in factory premises. And same can hold true for other chemicals as well. Greenpeace in 2002 observed that concentration of the left over chemicals was too low to cause acute toxicity[14]. Later in 2005 only Sevin residue, semi processed pesticide, contaminated soil and lime sludge[15]could be identified.

Now these chemicals found in the soil of factory premises raised three problems: one what is their quantum and toxic potential over the years, second what are the chances of the contamination of ground water table and the third their disposal modalities.

Some of these chemicals, if not all following exposure to natural forces like sun light, moisture, heat and cold over the years may have denatured and got converted to either more harmful or harmless substances. But all agencies agree that soil inside the factory premises is contaminated and according to some up to depth of two meter. Further the possibility of the acute toxicity has already been ruled out by one group and the possibility of chronic toxicity is simple speculation. As after acute phase so far, not single chemical has been directly linked to its known chronic toxic symptomatology even in single persons of the 500,000 gas affected population over last 28 years. But the matter should not be closed just due to non availability of the data; rather it is suggested to conduct a study on presence of toxic chemicals in the body and linking them with the present symptomatic status among at least 5000 surviving severely/ moderately / mildly affected population.

The issue of contamination of the ground water needs a little examination. It has been found that the soil structure does not permit toxicants migration at faster pace[7]and chances from the water contamination through solar evaporation ponds were too less as the ponds showed presence of aldicarb and a- Naphthol in traces only[41].

Hence, with presumably impermeable soil and impermeable polyethylene sheet around solar evaporation ponds, low toxicity potential material, kept protected since 2005 were the factors which controlled the level of toxicants in the ground water.

Before the issue of water contamination is taken up one has understand that water from two sources is under consideration; one the ground water and the second the water being supplied from other sources as per the instructions of the honorable Supreme Court of India. During the period pertaining to 1985-2006, 13 reports on ground water evaluation could be procured and of the 13 occasions at least six times it was found to be of potable quality. Finally NEERI in 2010 affirmed that the dumps in general have not contaminated the ground water and CSIR-IITR in 2013 found that presence of inorganic Lead in ground water was not due to UCIL activities and presence of HCH could be due to agricultural/ horticultural activities in surrounding areas[30]. And for this reason this water is not fit for consumption. Lastly, the water being brought from Rasalakhedi needs to desalinized and disinfected before it is used for human consumption. At this juncture authors would like to submit that a study to link lead poisoning with it's established symptomatology if found among the gas affected population as cited above would give clearer picture. And secondly, it would have been better if the water from new Bhopal city could have been compared for same toxicants.

No doubt the human hosts and even animals too were contaminated with the MIC or its break down products, Carbon monoxide and Cyanide poisoning during acute phase. The phenomena of N Carbamoylation, indicative of MIC poisoning came to end by March 1985[34].COHb and MetHb indicative of CO poisoning declined significantly 3 months post disaster[38]. Pre injection level of Thiocyanate were found low and post Sodium Thyosulphate injection level were observed to be low by march 1986 indicating exhaustion of cyanide toxicity[42]. And by one year post disaster 2-3DPG levels and one and half years post disaster high Hb (due to binding of MIC to end terminal valine residue of Hb) levels returned to normal indicating normalization of oxygen carrying capacity of hemoglobin[43]. Theoretically it appears the impact of human contamination during acute phase was over by mid1986.

During chronic phase single explanation for inability of stored chemicals to cause symptomatoplogy besides above is possibly inability of these chemicals to enter food chain as nothing is grown or cultivated in densely populated affected area.

Issue of decontamination of the chemicals inside the factory premises and the premises itself has been a topic of hot debate and need immediate attention as more the delay more the possibility of all round contamination. Competent authorities have suggested modalities for same. These include decontamination and decommissioning of plant, machineries and buildings, fencing and security to UCIL premises and SEP area, immediate sealing of five contaminated wells, excavation and recovery of dumps materials, offsite disposal of incinerable waste, onsite disposal of non-incinerable wastes in secured landfills. For remediation of 11,00,000 mt. contaminated soil, an on-site secured landfill facility and for contaminated groundwater, pump-and treat system was recommended[15].

In summary one can say that by and large the air is free from contamination by Union Carbide, the water as such is minimally contaminated and the soil needs immediate remediation to save water from further contamination. In fact decontamination issue is long pending and decontamination exercise should be taken up on war footing and it is time to act now.

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