Surviving Bhopal 2002

Toxic Present - Toxic Future

A Report on Human and Environmental Chemical Contamination around the Bhopal disaster site

by

Srishti
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For the Fact Finding Mission on Bhopal

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The Bhopal Fact Finding Mission was set up to investigate the current state of the people and environment at the Bhopal disaster site. The mission focused on different aspects namely medical and mental health, environmental, economic, legal and social status of the people living in and around the UCIL plant. Specialist coordinators working on a voluntary basis headed each area of work. This report relates to the environmental aspect of the work.

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1. Bhopal - The Toxic Noose

What should one do if the food, the soil, the water, and ones own body is contaminated with toxics? Where does one turn, how does one cleanse oneself, just to be able to live healthily and support a livelihood? Where does one turn if there is no access to any resources, and no one is prepared to even believe in your suffering? Can human rights be more violated, than through the slow everyday creeping of poison in ones body, through processes unleashed by a powerful corporate, which is now nowhere to be seen? To protect the citizen is not the reason why we have a Constitution, laws, to be able to have a Right to Life and a healthy one? Should not any environmental and health policy basically attempt to ensure just this? The ongoing saga of the Bhopal tragedy and this report confirms that this is exactly what is not happening.

As the following report once again evidences, Bhopal did not just happen on December 3rd, 1984, it is continuing to happen to those who were unfortunate to live in its vicinity on that fateful day. Not only this generation but the next generations too stands to be contaminated and poisoned by the disaster. Not only is the soil, but also groundwater, vegetables as well as mother's breast milk has found to be contaminated.

1.1 Toxics Entrenched

All media, soil, ground water, vegetables, breast milk investigated were found contaminated by heavy metals, and organochlorines to various degrees. The evidence suggests that the toxics had not only moved across various mediums but had also become part of body burdens. As is well known, some of these toxics accumulate in human fat, and are passed onto the next generation through mother's breast milk. The effects on the infant are traumatic, not only in terms of the amount of toxics, which it receives, and it can exceed a lifetime supply, but also in their nature. Current toxicological knowledge shows that there may be no acceptable level, which can lead to health effects. In children this is especially true since low dosage toxicity can lead to endocrine disruption and hormonal malfunctions, effects of which may only emerge at puberty in some cases.

1.2 Cleanup?

Post contamination clean up is often used as a safety valve when a toxic hotspot has been created through corporate misendemours. However the reality is very different. Can these sites ever be cleaned up? The polluter pays principle is cited in this case. However, more often than not polluters do not pay, and resist attempts to make them do so. Or the amount the polluter may have to pay to clean up the soil and groundwater, even if it were possible, of all the multiple types of toxics there may be, the cost could threaten the existence of the polluter itself. It is hardly likely that such a drastic annihilation for the sake of a mere toxic site would be allowed, or if State laws would push enough to make this happen.

In the US, where clean up has been legislated through their superfund provisions, already there are more than 85,000 known or suspected hazardous waste sites across the country, and the worst 1,300 are listed as Superfund sites. According to the US based NGO PIRG, "Ever since Superfund was created, insurance companies, polluters like DuPont, General Electric, and Union Carbide, and industry trade associations including the Chemical Manufacturers Association (CMA) and the American Petroleum Institute (API), have lobbied Congress to roll back the polluter pays principle and weaken cleanup standards at the nation's worst toxic waste sites. In addition, these groups have fought efforts to expand the public's right to know about toxic chemicals used in the workplace, consumer products and communities."

" Companies seeking to roll back Superfund, the nation's toxic waste cleanup law, gave nearly $100 million dollars to congressional candidates between 1991 and 1997, according to a report released today by U.S. PIRG. The report, Polluter Pay-Off: The Multi-million Dollar Campaign to Roll Back Superfund, details the money given to congressional candidates by 188 political action committees (PACs) of some of the nation's largest oil, chemical and insurance companies as well as trade associations for their industries."

1.3 Corporate responsibility

The post Bhopal era saw the industry coin new terms: Responsible Care is one of them. However, as can be seen time and again Responsible Care or similar corporate responsibility statements are lip service. How does one explain then the dumping of mercury in South India by one of India's largest corporate, Hindustan Level, also an arm of the international giant Unilever? Or the fudging of EIAs by some of the best known consultants in the world? It increasingly seems that corporates will be as responsible as will be permitted by the community. An unaware disempowered community cannot negotiate a corporate to be responsible.

2. Policy and Legislation

The Bhopal disaster was a watershed in the area of environmental policy and legislation worldwide. Suddenly the horror of the industrial model of development became very stark and real. How and where industries were sited, how they dealt with the dangers which they posed to the communities around them became real questions. After the Love Canal saga, Bhopal probably was one incident, which led to worldwide regulation on chemicals and toxicity. Intertwined with all the information was the fact that communities needed to know and be provided information, besides being participants in industry siting decision making.

Later in 1990, an EPA analysis compared U.S. chemical incidents in the early to mid-1980s to the Bhopal incident. Of the 29 incidents considered, 17 U.S. incidents released sufficient volumes of chemicals with such toxicity that the potential consequences (depending on weather conditions and plant location) could have been more severe than in Bhopal. As a result of this, the *Occupational Safety and Health Administration* (OSHA) was asked to develop programs to prevent chemical incidents, and the US Congress authorized EPA to promulgate the *Risk Management Program Rule (40 CFR 68)* for protection of the public, and OSHA to promulgate the *Process Safety Management Standard (29 CFR 1910.119)* to protect workers. The Amendments also established the independent U.S. Chemical Safety and Hazard Investigation Board.

While in India too, the post Bhopal scenario realigned thinking on the impacts of chemicals on human health and the environment is in many way, however this it has not translated into practice. The Bhopal disaster led to a political environment where the State had to act, or at least seen to act against such a horror story being repeated. India enacted the wide seeping Environment Protection Agency in 1996, which became the basis of the various laws over time, which deal with toxics effects of chemicals. On the face this Act led to a new framework of legislation to ensure that Bhopal is not repeated.

Yet the focus on all the laws was to manage the toxicity and the waste. The titles of the Rules enacted under the Act, also said as much. Management and Handling became the key words for environmental and human health protection in their intentions. Even though the first Indian policy statement on pollution abatement clearly marked out pollution prevention as the primary intent of the State, this has never translated into practice. The laws lead automatically to the technical path of regulation, and end-of-pipe solutions, without examining the processes, which led to the generation of these hazards themselves.

The inefficacy of this approach was revealed when the Supreme Court started investigating the matter, prompted by a PIL. The ground situation was disastorous. There were probably many more Bhopal's waiting to happen. In some senses the laws have provided a sense of security, and legitimized the continuance of a toxic legacy. There has been a reluctance to take stern action on a non-complying industry, and the matter of reporting becomes a private affair between the polluter and the regulator since there is no provision for any public disclosure of information. Not only is the regulator incapable of regulating but also in many cases, owing to political interferences or just mere corruption is unwilling to do so.

The common person has little rescourse in such a situation. People are not only alienated through the language of science but also not allowed access to any documents, which may threaten their safety. Industrial siting has not improved too. Industries continue to come up in urban centres and lead to concentrations of large communities around their periphery. Accident preparedness in non existent and the designated local officers entrusted with the tasks of responding in an Bhopal like emergency often are not even aware that they have this responsibility leave alone how to react.

Also the State refuses to act on the basic requirement of better environmental governance that of public information and disclosures, which are almost non-existent in our laws. While the world moved onto legislation such as Toxics Release Inventories (TRI), forcing industry to release data on its emissions, the Indian citizen does not even have the right to know what is going on in next door. In fact there is very little pressure on the corporate to comply with any emission law. Industry siting too has been garbed in ineffective processes such as the Public Hearing processes where Environment Impact Assessments (EIAs) are routinely put up for public comments, and cleared despite any objection that may have been received. The process of information, and public involvement has been totally obfuscated and made mockery of. Consultants are known to ensure that their corporate clients will not only receive an EIA for a proposed project but will also get clearance for them. Industry at any cost is the State line, and anything which stand in the way is quickly overcome, either through a perfunctory and meaningless process, geared to rubber stamp approvals, or through even enacting amendments to existing laws. For example this has recently happened in the new EIA laws, which remove the need for an assesment to be carried out if the project is a small scale one. It is open to question how the scale of operation changes the possible environmental impact of a process, especially if it my entail highly toxic chemicals and wastes.
Recognising the impact of such chemicals on human health then is a far cry. In fact there is such a dearth of data on health impacts, which has been made public, that

on would assume that there is no harm being done. The truth is of course far from that. Human health concerns have driven environmental policy round the world, and is the basis of the rejection of the risk assessment approach by many environmental groups worldwide in favour of a precautionary approach.

Such is the state of affairs more than 15 years after the worst industrial accident took place. One can only place the blame on a complete lack of will of the State to act in favour of the citizen. Instead of venturing down a path of clean development and attract the best process in the world, we have set our minds to development at any cost. People have become mere statistics, especially if they are marginalised, poor and voiceless. The Bhopal disaster, and its ongoing human tragedy have not taught us any lessons. In fact we have just no wanted to learn.

2.1 Legislative framework

There are various legislation pertaining to the prevention and control of pollution in India. Even Constitution's 42nd amendment under the Article 48 A, the provision which deals with the protection and improvement of environment reads: "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country". The Courts through various judgements (*Kinkri Devi, L.K. Koolwal*) have also taken a note of provisions of Article 21 and held that environmental degradation violates the fundamental right to life.

There are various laws governing the environment and labour protection and set reasonably good standards, but the implementing machinery is weak and funding of facilities poor. There is too much emphasis on government and its machinery but little or no scope for workers or the community to intervene effectively. The various related laws are:

- *Water (Prevention and Control of Pollution) Act of 1972;*

- *Air (Prevention and Control of Pollution) Act of 1981;*

- *The Environment (Protection) Act, 1986,*

This Act was enacted to implement the decisions taken at the UN Conference on the Human Environment held at the Stockholm in June 1972. This is the first comprehensive law, which covers air, water and noise pollution as also other matters relating to industrial and environmental hazards, including the handling of hazardous material. But this gives a very little right for workers or the community to take action against the polluting units. There is no provision for right to information, no right to take samples, monitor and sue the industry under EPA, unless the government and its authorities co-operate.

- *Hazardous Processes & the Factories Act, 1948:*

The Bhopal Gas Tragedy and the Oleum gas leakage from Shriram Foods and Fertilisers, lead to the amendment in the 1987 to the Factories Act, 1948. The amendment has introduced special provisions related to the hazardous industrial processes in an effort to tackle the risks and dangers not only to the workers but also to the general public residing in the in the vicinity of the factory.

- *The right to information:*

The law makes it compulsory for the occupier of the factory to disclose all the information regarding dangers, health hazards and the measures to overcome such hazards, in case of hazardous processes to the workers, Chief Inspector of factories, the local authority and the general public.

- *Worker's Right:*

Under the Sec. III- A of the factories Act, the workers have a right to:

  - Obtain from their Employer information relating to their health and safety at work;
  - Get trained within the factory or get sponsored by the employer for getting such training.
  - Represent to the Inspector directly or through union representatives in the matter of inadequate provision for the protection of their health or safety in the factory.

- *Manufacture, Storage and Import of Hazardous Chemicals Rules of 1989:*

The main purpose of this rule is to regulate handling and storage of hazardous chemicals and to prevent and contain accidents from the industrial activities and storage involving such hazardous chemicals. Rule 14 requires the Authority specified under the under the column 2 of the schedule 5 to prepare and keep up-to-date an adequate off-site management plan detailing how emergencies relating to a possible major hazard on the site would be dealt with.

- *Public Liability Insurance Act, 1991:*

  The Act was passed to provide public liability insurance for the purpose of providing immediate relief to the person affected by an accident occurring while handling any hazardous substance and for matters connected therewith or incidental thereto. It also provides for liability to give relief in certain cases on principle of no fault. It will be the duty of the owner to take out insurance policies.

  The Rules provide the list of chemicals with quantities for application of public liability insurance act.

Authority (ies) with legal backing	**Duties and corresponding rule**
1. MoEF under the EPA –1986	Notification of the hazardous chemicals as per rule 2(e) (i), 2(e) (ii) and 2 (e) (iii)
2. Chief Controller of Imports and Exports under the Import and Export (Control Act), 1947	Import of Hazardous chemicals as per rule 18
3. CPCB and State Pollution Control Board under EPA- 1986.	Enforcement of directions and procedures in respect of isolated storage of hazardous chemicals like: - • Notification of major accidents as per rule 5(1) and 5(2) • Notifications of site as per rules 7 and 9 • Safety reports in respect of isolated storages as per rules 10 and 12 • Preparation of on-site emergency plans as per rule 13
Chief inspector of Factories appointed under	Enforcement of directions and procedures in respect of industrial installations and isolated

the Factories Act, 1948	storages covered under the Factories Act, 1948, dealing with hazardous chemicals and pipelines • Notification of sites as per rules 7 to 9 • Safety reports as per rules 10 and 12 • Preparation of of-site emergency plans as per rule 13 • Preparation of off-site emergency plans in consultation with District Collector or District Emergency Authority.
District Collector or District Emergency Authority designated by the State Government.	Preparation of off-site emergency plans as per rule 14

- *The Emergency Planning, Preparedness and Response to Chemical Accident Rules (EPPRCA)*

The rule notified in August 1999 provide specific focus on the management of chemical accident emergencies. The regulation requires the management of chemical accident and the key requirements/provisions are.

- Formation of a Central Crisis Group and Crisis Alert system (by the Central Government) with defined functions and roles.
- Formation of State Level, District Level and Local Level crisis groups by State Governments with defined roles and responsibilities in the planning.

Under the Environment Protection Act (1986), "*The Manufacture, Storage and Import of Hazardous Chemicals"*, rules were passed in 1989 to ensure that chemical handlers appropriately warn employees, maintain a safe workplace and are prepared if an emergency situation should occur. The rules also places responsibility in the hands of different government bodies, called Authorities. These laws are applicable depending on the type and quantity of chemical that one is handling.
Some basic responsibilities of Authorities include[i]:

- Inspect the industrial activity at least once in a calendar year (Rule 3a).
- Prepare and keep current an adequate off-site plan containing details of how emergencies relating to a possible major accident on that site will be dealt with (Rule 14).
- Ensure that a rehearsal of the off-site emergency plan is conducted at least once a year (Rule 14).
- Make a full analysis of accident reports and channel them appropriately (Rule 5).

Some basic responsibilities of handlers include[ii]:

- Gain approval from the appropriate authority before undertaking any activity. This information must include data on the chemicals that will be handled and the maximum that may be found on site at any given time (Rule 7).
- Notify the appropriate authority if there are any applicable changes in the operation such as the quantity or type of chemicals handled (Rule 8).
- Prepare and update annually, a safety report containing information on the industrial activity, identification of all possible hazards and description of how an emergency will be handled, at least 90 days before commencing that activity (Rule 10).
- Identify the major accident hazards (Rule 2a).

- Take adequate steps to prevent such major accidents and to limit their consequences to persons and the environment (Rule 2b-i).
- Provide to the persons working on the site with the information, training and equipment including antidotes necessary to ensure their safety (Rule 2b-ii)
- Take appropriate steps to inform persons outside the site who are likely to be affected about the nature of the major accident and the actions, which should be taken in the event of an accident (Rule 15).
- Prepare and maintain a safety data-sheet to be accessible upon request. This should identify characteristics, health hazards and safety precautions for each chemical (Rule 17).
- Properly label every container of a hazardous chemical clearly. This should identify the contents of the container, the manufacturer and the physical, chemical and toxicological characteristics of the chemical (Rule 17).
- Prepare and maintain an on-site emergency plan containing details on how major accidents will be dealt with and conduct a mock drill of the plan every six months (Rule 13).
- Notify the concerned authority within 48 hours should a major accident occur and furnish a report to the concerned authority with required information (Rule 5).

3. Industrial Siting

Siting is another key issue from an environmental perspective. Siting has many dimensions in India, and has been a key reason for conflict. Often siting is not given adequate importance, as can be seen in the haphazard growth of urban centres in India, as well as the distribution of industry in and around towns. Till date there are no siting laws, only guidelines, though there is now a proposed law.

Siting problems have also been the reason for very active Supreme Court action in the recent past. Some of the key judgments have related to relocating industry or pushing it to use cleaner fuel, such as natural gas. For example, industry has been asked to shift from Delhi as well as the Taj Trapezium, leading to immense human trauma to those working in it.

Poor siting has also led to the growth of cities such as Delhi, Mumbai and Kanpur, owing to the location of Industry here. Such cities are now centers of industry and commerce, leading to high level of pollution. The Bhopal gas disaster of 1984, was an outcome of poor siting, leading to a high death toll following to the high population density adjoining it. Such a trend is being increasing observed in the growing towns of India, and is a worrying feature, since industrial areas have not been clearly defined or located.

There have been numerous responses to decongest such cities from such industrial activity in the recent past. Amongst them is the massive proposed location of over 90,000 industrial units in Delhi, and the relocation of polluting industry near the Taj Mahal. Such relocation has a high human cost, further leading to strife and conflict.

It was in response to one such trend in the capital city of Delhi, that in a case filed by NGOs to prevent an infrastructure hotel's complex form being built in the city, the Supreme Court of India set up a special Environmental Impact Assessment Authority in October 1996, to examine all infrastructure projects in the National Capital Region Delhi, and which has not been transformed into the Environment Protection and Prevention of Pollution Protection Authority since January 1998. This Authority has the powers to reject any infrastructure project in the area on the basis of its environmental impact, which includes siting.

3.1 EIAs

All industrial projects involving an investment amount of Rs 50 crores need to carry out an environmental impact assessment. The Assessment, which is mandated in law under the EIA notification, has a strong component of siting, guided by the Industrial Siting guidelines of 1985. However, of late many projects have been proposed in hitherto inviolate zones such as protected areas, coastal zones, and there is a general pressure on previously agricultural land to be converted to industrial zones. In fact some of the hazardous industry asked by the SC to shift out of Delhi has relocated in the periphery nearby town of Alwar, on agricultural land.

The location of industry is hence slowly changing the face of cities as well as what was earlier rural and agricultural India. There are also local demands from those residing in rural areas to locate industry since these provide jobs and livelihood, to those who were earlier agriculturally based, or were hitherto landless. In Gujarat for example, sugarcane factories are dispersed amongst agricultural land, and share water and air resources with them. In many senses the rural economy is becoming industrialized, since both the crops being grown as well as those employed have either urban market linkages or are part of the extended industrial resource base, such as sugarcane for sugar factories.

Expectedly then, industrial siting is a very political issue. Both the Industry as well as various state governments, see industrialization as key to prosperity, and do not wish to be hampered by any environmental constraint such as siting.

3.2 Siting Process

The first emphasis on industry siting was brought about by the publication of the `guidelines for industry siting' almost fifteen years ago in 1985. Subsequent to these guidelines the Environmental Impact Assessment (EIA) Notification in 1995 lay down the basic procedures to be adopted for the siting of Industry. However the guidelines were not mandatory, and only served, as inputs to the EIAs which were required for certain Industries for obtaining Central clearance for siting.

There have been a number of related efforts to make industry siting a more scientific and ecologically sound process. Amongst these are sections of the CRZ Act (Coastal Regulatory Zone), which prohibits the setting up of industry (amongst other activity) from within 500 m of the high tide line, the Zoning Atlas for Industries project of the CPCB wherein a detailed district wise plan for industry siting based on GIS systems is being developed, and the inadequate Public Hearing Notification April 1997, which makes it mandatory for any EIA presented to the Government to be publicly debated in the area of siting before it is finally cleared.

An experts committee evaluates all EIAs submitted to the Centre. However the experts advice is not taken seriously. Projects are often cleared with recommended changes, which are not implemented especially if the project proponent is a State Body. In the case to the TEHRI dam the experts committee recommended the dropping of the large dam project owing to it not meeting environmental requirements. However a subsequent Committee of secretaries cleared the project irrespective of the advice, and even though it had no environmental expertise. The decision was a political one.

The new proposed Environmental Siting Rules had a series of reactions to the proposal, before they were notified. The Industry felt that those areas with low pollution potential should be taken off the list, as also the 25 Km band should be reduced to 10 Km, stating that the `maximum ground level of pollutants rarely occur beyond 7 Km form their sources…. And that 10 Km would provide adequate safety'[1] It also felt that these restrictions should only be applied to mega-cities of population more than 2.5 million, and that pushing a 25 Km band law would locate industries in rural areas per force.

The Government of Gujarat reacted particularly strongly. In a letter to the Secretary MOEF, the Chief Minister declared the draft as "rigid and draconian,' stating that the "circle approach" to protecting the "so-called" ecologically sensitive area as not acceptable, since it would seriously "hamper industrial growth, virtually placing the development on a procrustean growth." Citing specific instances the letter says that it would adversely affect investment plans such as the new Indian Oil Corporation's refinery project, the Indian Petroleum Corporation's petrochemical complex, the

[1] Nivedita Prabhu, Industry protests against siting norms, The Economic Times, New Delhi, August 29, 1999.

Gujarat State Fertilizer and Chemical Complex, the Surat based KRIBHCO fertilizer plant, the Reliance Petrochemical complex and Essar Steel plant and the National Thermal Power Corporation's thermal power plant being amongst them

The new law will tend to shift the focus of Industry to rural and small town areas, which will have the potential to have a greater impact on agriculture. However, this has not been considered. Unfortunately, there is no specific focus on agriculture for the purposes of Industrial siting.

3.3 Public Participation

Public participation in industry siting is inadequately facilitated. Though all EIAs before they are cleared, need a public hearing through the *Public Hearing Notification* of April 1997, public information on siting is hard to access. Documents relating to EIAs and siting, as well, as the existing public hearing process does not require that decision reasons be made public, or that issues raised in the public hearing be addressed and made public.

In practice the public hearing process does not involve participatory decision making. The EIA is presented `after the fact' and does not call for participation, till it is too late. Often at this stage there is tremendous pressure and lobbying form the industrial group to have the project cleared irrespective.

Access to information is denied through various means. The law only provides for the availability of a summary of the EIA, but not the EIA itself and it has to be obtained at the State Pollution Control Board office, and even then cannot be photocopied. Often is too technical and not in a local language for the community to make much sense of it.

Information, even if available, is often too technical for it to be used by the community. Often those whose areas the project is slated to come up in are illiterate or unaware of the real impact that the projects might cause. Hence the questions which are posed at the public hearings, often relate to employment opportunities and the ability of the project to provide schooling for children, rather than on other impacts such as on their livelihoods, agriculture, waste dumping etc.

The law itself is silent on the mechanism of redressal of the questions raised in the public hearing. There is no mechanism to ensure that the questions raised are taken account of or the decision of siting changed. The proceeding of the hearing itself are not made public, and the addressal of the queries not documented. Often the Public Hearing is attended by middle of low level functionaries in the State Pollution Control Board, and other local bodies and the process is often perfunctory.

Very rarely have projects been relocated as an outcome of this process, though in more high profile and visible siting, there is an effect. (See EIAA in Urban Planning and Land Use chapter). Some NGOs such as Toxics Link in Delhi are producing information, which can help community groups to evaluate complex projects and to aid them in making the public hearing exercise more effective.

However public hearing implies a people's power to influence a decision. Even though the formal notification came only recently, and that too in a very incomplete way, there has been a tradition of `peoples tribunals' being held on environmental issues in India.

One such series of IPTs which were held recently in end 1998 and early 1999, were by the Human Right's Law Network a Mumbai based NGO which is legally oriented. Normally such tribunals have a public hearing by a panel consisting of lawyers and retired judges. The report is then published, and is used by the media as well as the community as a testimony to their grievances. These also result in public interest litigation.

Another IPT was held by the Mazdoor Kisan Shakti Sangathan a landless agricultural labourers group for outsees of the Bilaspur dam in Tonk district, Rajasthan, in February 1999.

4. The Reality of Implementation of Laws in India

4.1 *The case of India's hazardous waste – Bhopals in waiting*

The High Powered Committee (HPC) on hazardous wastes constituted by the Supreme Court of India in 1997 under the Public Interest Litigation filed by the Research Foundation for Science, Technology and Ecology (1995) recently submitted its report to the apex body, highlighting the state of India's hazardous waste management. In the Chairman's foreword, Prof MGK Menon noted that the "*situation in regard to hazardous wastes in the country is grim. It particularly affects the groundwater systems of the country and remediation is very difficult and expensive. It affects a large numbers of innocent people, workers as well as community, who have to pay for the sins of others*."

Government apathy towards managing hazardous wastes is apparent from the fact that there is no reliable data available on the quantum and nature of hazardous wastes generated in the country. In the last three years, the Ministry of Environment and Forests have reported four different figures on the quantum of hazardous wastes generated - 0.7 million tones (MT)/ annum in 1997, 9 MT/annum in Jan'2000, 8 MT/annum in Feb'2000 and 4.4 MT/annum in May 2000.

Though the figure is incomplete, the approximate number of hazardous waste generating units in the country is 13,011, out of which 11,138 are authorised and 1873 are illegal according to the HPC report.

4.2 Disposal of hazardous wastes

The situation is alarming as far as the disposal of these wastes is concerned, to say the least. Due to lack of any infrastructure, both due to government's negligence and industry's lack of concern, hazardous wastes is finding its way:

- Along the roadside
- In low lying areas
- Along with the municipal refuse
- On river/canal beds
- In empty spaces within industrial estates[2]

The HPC found hazardous waste being dumped along with municipal wastes. The leachates from such areas may be toxic or infectious, seriously contaminating both agricultural land and groundwater aquifer.

As per the HW Rules, 1989, and the MoEF's 'Guidelines' (1991), hazardous waste generated by industries has to be disposed of in Secured landfill Facilities. The responsibility for identification of sites under the HW Rules, 1989, for the disposal of hazardous waste rests with the respective State Department of Environment. The sites must be located after carrying out EIA's.

The MoEF, in 1992, formulated a scheme, and thereafter provided financial assistance of Rs 5-15 lakhs to15 states for identification of disposal sites conducting EIA studies. Despite this, till 1997, there was not a single Secured Landfill Facility

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[2] Report of the HPC on Management of Hazardous Wastes, vol.1, page: 97, 2001.

(SLF) available in the country to dispose of hazardous waste. Only recently three common disposal facilities have come up in the state of Gujarat and one in Andhra Pradesh.

Infact, State Pollution Control Boards of Gujarat and Andhra Pradesh, on a preliminary listing, have reported that they have "more than 40 illegal hazardous wastes dump sites in each state". The cost of remediation of these sites, which have severely contaminated the ground water and soil, will run into millions of rupees, which will be borne by innocent citizens in the form of taxes. As a case in point, the rehabilitation of 350 hectares of contaminated area from toxic effluents in Bichhri, Rajasthan is expected to cost Rs 44 crores.

Table (1) State-Wise (Available) Hazardous Waste Disposal Options[3]

State	Disposal Options	
	No. of Incinerators	No. of eng. Landfills
Andhra Pradesh	20 In Ida	2 TSDFS are planned
Assam	Nil	All units have their own on-site disposal sites
Bihar	Nil	2 proposed
Chandigarh	Nil	Nil
Delhi	-	-
Goa	1	Nil
Gujarat	30	12 are operational
Haryana	7	1(Faridabad site notified)
Himachal Pradesh	-	-
Karnataka	6	4 (On-Site)
Kerala	5	16 (On-Site)
Maharashtra	16	8 sites are being
Madhya Pradesh	8	16 sites identified & 3 notified
Orissa	Nil	3
Jammu & Kashmir	-	-
Pondicherry	1	-
Punjab	9	-
Rajasthan	6	23
Tamil Nadu	10	23+2 under construction
Uttar Pradesh	9	11 identified, 1 acquired, EIA for 8 districts done
West Bengal	Nil	Nil
Total	116	

As indicated in the above tables there are about 116 industrial incinerators in the country, mostly in Maharashtra, Gujarat, Tamilnadu and Andhra Pradesh. According to the HPC, most of these are merely "combustion chambers or industrial boilers where the maximum temperature is around 500-550º C". This is of particular concern since dioxins and furans, two most deadly toxins produced during burning of chlorinated compounds, ideally form between the ranges of 400-600º C. The type of

[3] Report of the HPC on Management of Hazardous Wastes, Vol.1, page: 103.

wastes being burnt in these incinerators includes wastes from oil refineries, pesticides, drugs, petrochemical. All of these wastes contain chlorine.

4.3 Present situation in Bhopal

According to the newspaper reports, people living in the vicinity of the Union Carbide Ltd in Bhopal are scared of the 'Hazardous Waste' lying in the factory compound. There is a growth of high grass and bushes in the compound, if it catches fire then the toxic fumes and gases will be emitted out of the waste.

There is also probability of Toxic Waste leaching to the ground and polluting the groundwater acquifers.

According to Shri Chauhan, a former employee of Union Carbide and currently with District's Industrial Area Dept says that in the compound of the UCL about 25 chemicals and 'hazardous wastes' lying in there. They are Methyl Isocyanate, Methyl Chloride, Carbon Tetra chloride, Methanol, Phosgene, Chlorine, Tar coal, Mercury, Naphthalene etc and many more.

There is thus an urgent need for a right to information and citizen's action: Citizen action is one of the most effective ways of ensuing long-term change. In order to adequately act however, people must be able to access information in an efficient manner. The Bhopal tragedy spurred the passage of several community right-to-know laws in several countries in the mid 1980's. The idea behind the right-to-know is that if someone is being exposed to a chemical, he has the right-to-know about it. As a result, community members can now access information about contaminated sites and about pollutants being emitted into their neighbourhoods. In India, however, community struggles have had little success in winning the "right-to-know" for us. People should be able to identify any contaminated sites in their area and chemical emissions to the air and water. Giving individuals the resources with which to fight will help keep industry in line and will produce a better-informed citizenry.

5. Summary of Findings

5.1 SOIL SAMPLES

Heavy metals
Among the four heavy metals analysed in the soil samples in residential areas around UCIL, nickel was the most prevalent one. Five of the six soil samples showed nickel contamination, while chromium, mercury and lead were present in three each and two samples, respectively.

The soil samples in the UCIL factory were analysed from four different sites, as different types of chemical reactions were confined to different areas within the factory. Soil samples mostly showed the presence of chromium and nickel.

Mercury was detected in higher levels in the samples collected from the alpha-napthol site and below the Pan filter site. Nickel was present in four of the five sites within the factory premises, while mercury was present in two sites at almost similar quantities, but their levels were comparatively high.

Pesticide HCH (BHC)
The total HCH (BHC) pesticide concentrations in the six soil samples were 9 mg/Kg. The average value of its concentration was 1.60 ppm. Among the six residential areas, J.P Nagar had the highest level of the pesticides HCH with a level of 5.038 mg/Kg, while Nawab Colony, Atul Ayub Nagar had almost similar levels, exceeding slightly over 1 ppm. Among the HCH isomers, the proportion of gamma- HCH exceeded those of beta- HCH.

Among the four sites in the factory premises, the HCH levels were highest at the Sevin Shed. The total HCH in this area was slightly over 8 mg/Kg, which was five times more than those were present in Sevin plant site-I. The Solar Evaporation Pond, which was dumping site outside the premise, showed very low levels of the HCH isomers.

Volatile Organic Compounds (VOC's)
Among the residential areas, J.P. Nagar showed the highest contamination of Volatile Organic Compounds (VOC's) followed by Kanchi Chola, which showed 7.5 times lower than that of J.P. Nagar. Dichlorobenzene was the predominant contaminant in most of the cases. The total VOC level found in the soil samples were 5.86 mg/Kg while their average was slightly lower than 1 mg/Kg. Among the six soil samples, Dichlorobenzene, 1,3,5-Trichlorobenzene and Tetrachlorobenzene were present in all the samples.

All the soils tested for VOC's in the UCIL factory showed positive results. All the soils from the factory site showed Dichlorobenzenes, 1,3,5-Trichlorobenzenes, 1,2,4-Trichlorobenzenes and Tetrachlorobenzenes. Among the four sample sites, the Sevin Shed showed the highest concentration of VOC's. The amounts of VOC's at the other three sites were more or less similar. The total VOC content in the samples was 1.855 mg/Kg while the mean levels in the factory premises was 0.463 mg/Kg. The total VOC content in soils from the Solar Evaporation Pond was found to be 0.268 mg/Kg.

Halo-organics: Dichloromethane and Chloroform
Among the six soil samples from the residential area, Dichloromethane was present in all the samples. The levels ranged from 0.082 to 0.170 mg/Kg with an average amounting to 0.103 mg/Kg. The soil samples from Kanchi Chola showed maximum concentration of Dichloromethane, which was almost twice as compared to the other areas. The other residential areas showed more or less similar amounts of this contaminant.

Chloroform was present in all samples and most of the soil samples contained this compound at fairly similar levels. The average chloroform level in the soil sample was found to be 6.55 mg/L. The highest concentration of chloroform found at Atal Ayub Nagar was 6.77 mg/L, while the minimum found at Kanchi Chola was around 6.27 mg/L.

Soil samples within the factory premises showed both dichloromethane and chloroform. The chloroform in the samples in the factory exceeded those of dichloromethane. The chloroform and dichloromethane levels were almost similar at all soil sampling sites in the factory. The average level of chloroform in the soil was 6.40 mg/Kg, which was 50 times more than dichloromethane.

5.2 GROUND WATER

Heavy metals
Among the ten ground water samples collected from the residential areas around UCIL, all samples contained chromium and nickel, while mercury was present in six and lead in eight water samples. Nickel was the predominant contaminant in water, with an average of 1.0990 ppm, followed by mercury, chromium and lead whose average levels were, 0.567, 0.026 and 0.122 ppm, respectively.

Pesticide HCH (BHC)
The total concentration of the pesticide HCH in the ground water samples from the residential areas was 0.0898 mg/L. The mean level detected in water was 0.011 ppm. Water samples from Anu Nagar and Shakti Nagar were most contaminated with the pesticide HCH, while the other areas had almost similar levels.

The water tested from the factory premises showed 0.115 mg/Kg of the pesticide HCH. This level is ten times more than those present are in the residential areas around the factory.

VOC's (Volatile Organic Compounds)
The concentration of VOC's was highest in Kanchi Chola, while a marginally lower level was found in Anu Nagar. In the other areas, it was almost two to ten times lower than these areas. The mean concentrations of VOC's in the ground water samples of the residential areas were found to be 0.050 mg/Kg. Table 21 indicates the VOC's in ground water samples from the UCIL factory premises.

Water samples from the factory premises contained 0.0331 mg/L VOC's while those from a water pond adjacent to the Solar Evaporation Pond contained 0.008 mg/L VOC's.

Halo-organics: Dichloromethane and Chloroform
All the eight ground water samples contained both dichloromethane and chloroform. However, the dichloromethane levels in water were almost 2 times more than chloroform. Water samples from Rajgarh colony had the highest level of dichloromethane. The average concentration of dichloromethane was 1.63 mg/L. The water samples from Atal Ayub Nagar showed maximum concentration of chloroform. The average concentration of chloroform in water was 0.85 mg/L.

5.3 VEGETABLES

Heavy metals
All the three vegetable samples grown at J.P. Nagar, showed chromium and nickel, while palak showed chromium, nickel, mercury and lead. The levels of heavy metals were found highest in palak than any other vegetables.

Pesticide HCH (BHC)
The total levels of HCH isomers in Brinjal and Palak were almost similar. The gamma-HCH isomer exceeded those of beta-HCH isomer.

VOC's (Volatile Organic Compounds)
Both the vegetables were found to contain VOCs. The dichlorobenzene was the predominant contaminant in the samples. The mean concentration of VOCs in the vegetable samples was found to be 0.132 mg/Kg. The concentration of VOC's was almost similar in both the vegetable samples analysed.

Halo-organics: Dichloromethane and Chloroform
All the three vegetable samples analysed showed the presence of both Dichloromethane and Chloroform. In palak, the dichloromethane levels were almost 30 times more than those present in either radish or brinjal. The average levels in the vegetable samples were 0.0284 mg/Kg.

Chloroform content was more in radish and brinjal when compared to palak. The average chloroform content in the vegetables was 7.51 mg/Kg, which was 264 times more than the mean levels of dichloromethane.

5.4 BREAST MILK

Heavy metals
The predominant metal detected in the breast milk samples was lead, which was found in seven of the eight samples analysed. Chromium was absent in the breast milk, while nickel and mercury were present in two and three samples, respectively. The mean levels of lead were marginally higher than mercury, although mercury was detected in fewer samples compared to lead.

Pesticide HCH (BHC)
All samples of breast milk showed the presence of pesticide HCH. The average level of the pesticide in the breast milk was 2.39 mg/Kg while the levels ranged from 0.179 to 11.44 mg/Kg. The breast milk sample from Shakti Nagar had highest levels for both beta and gamma – HCH when compared to the other samples.

VOC's (Volatile Organic Compounds)

All samples of breast milk contained VOC's. The total VOC content in breast milk samples was 17.12 mg/Kg. The 1,3,5 Trichlorobenzene was the predominant VOC and was present in all the samples. The sample from Shakti Nagar contained 9.52 mg/L and VOC was highest when compared to other samples. The average level of the VOC in the breast milk was 2.85 mg/Kg while the levels ranged from 0.588 to 9.52 mg/Kg.

Halo-organics: Dichloromethane and Chloroform

All the breast milk samples contained dichloromethane and chloroform. The amounts of chloroform were 3.2 times more than those of dichloromethane levels. The breast milk samples from J.P. Nagar showed highest levels of dichloromethane, while maximum concentration of chloroform in breast milk samples, were from New Arif Nagar. The average concentrations of dichloromethane and chloroform in breast milk were 0.359 and 1.154 mg/L.

6. Discussion

The objective of the present study was to establish the:

1. Presence of toxic contaminants in the factory premises and at dumping sites of the factory away from premises.
2. Quantitative estimations of the toxic chemicals.
3. Mobility of the chemicals.
4. Ascertain the presence of the chemicals in areas adjoining residential areas.
5. Trophic transfer of these chemicals, which essentially is through food chain to humans.
6. Exposure of human infants through breast milk.

The study clearly indicates that the factory is a source of chemical contamination since most of the chemicals used in the factory, are still present in factory and its adjoining residential areas.

The heavy metal nickel constituted up to 35% contamination, while mercury contamination was 21%. The heavy metal distribution was not uniform in different areas in the factory. Mercury was found at very high levels near the Pan filter area, Chromium was present at the Solar Evaporation pond and it constituted 7% of the various toxic chemicals detected at this site. The factory samples still showed almost 4% contamination of volatile organic compounds. The pesticide HCH constituted 40% of contamination near the Sevin Shed, was a point for the formulation of the pesticide Sevin with Lindane (gamma-HCH). Among the halo-organics, the Dichloromethane was fairly consistent amounting to 1% in all the factory samples. The most significant contaminant was chloroform amounted as high as 85% at SEP site, while at the factory it constituted 73% among the various contaminants at the alpha-napthol site, 65% at Pan filter site, 59% near the Sevin plant and 32% near the Sevin Shed.

The samples from the residential areas showed all the toxic chemicals present in the factory and its acquired premises. Among the toxic chemicals analysed in the soil, 56% constituted chloroform, 14% HCH isomers, 8% VOC's and 20% heavy metals. Among the heavy metals nickel constitutes 9%, while mercury and chromium amounted to 5 and 6%, respectively. The groundwater samples showed the highest concentration of dichloromethane, which amounted to 44% of the total toxic chemicals. The water also contained 23% chloroform and 30% nickel. In the vegetable samples, 77% comprised chloroform, while 20% constituted heavy metals. Mercury accounted to 9% while nickel and chromium amounted to 5 and 6%, respectively. The major contaminant in the breast milk was VOC's, which accounted to 40% of the total toxic chemicals detected. The pesticide, HCH formed 34% of the total toxicants, while chloroform constituted 16% of the contamination.

Results of the survey clearly indicate mobility of the toxic chemicals from the emanating source, the UCIL factory to the adjoining residential areas. Further there are no other chemical industries within the radius of 3-5 km from the factory, which have used the chemicals mentioned in UCIL inventory.

Chloroform, HCH, chlorobenzene, nickel and lead are the major contaminant in the residential areas. The UCIL factory was the source for presence of these chemicals in these areas. Chloroform was used as a solvent in the manufacture of methyl carbomyl chloride, an intermediate in Sevin production. Mercury was used s a sealant, while chromium and nickel were from corroded processing equipments and storage facilities. The pesticide, Lindane (gamma-HCH), was used in making a formulation with Sevin. The plant stored chlorinated benzenes; dichlorobenzenes and it had also manufactured these compounds on a small scale, before beginning with Sevin production. The trichlorobenzenes may have produced from isomers, produced during the manufacture of HCH.

The results clearly establish that there has been a serious environmental contamination due to UCIL factory. Although, it has been 16 years since it ceased to function, still, a number of chemicals are present and are making its way to other areas. It is evident, that many of organisms normally thriving in soil would have been wiped out from the contaminated areas. The vegetables grown in the interior of a residential area opposite to the front gate of the factory had the ability to absorb these toxic chemicals and transfer to the next trophic level of a food chain, which may be either herbivore or an omnivore, like human beings. Another very significant aspect is that the human breast milk showed maximum concentrations for VOC's and a higher concentration of the pesticide HCH. It is evident that these carcinogenic toxics are bio-concentrated in the breast milk. Hence, this poses a serious concern to infants, as it is the easiest and shortest route of exposure of number of these suspected carcinogenic chemicals.

No studies were conducted to see MIC in environmental and human samples, since MIC has a very short-life, although extremely toxic. In human autopsy tissues, MIC trimer was found in blood samples (Heeresh Chandra et al., 1991)

7. Toxicology of Chemicals found in the Residential Areas, Drinking water, Vegetables and Breast Milk.

7.1 *Chloroform*

It is a heavy colourless liquid with a pleasant odour. It had been extensively used in the past as an anesthetic. It evaporates into air where it breaks down to phosgene and hydrogen chloride; both of these products are toxic. It does not remain tightly bound to soil, hence easily percolates to the ground water, where it can persist for years.

Toxicological effects: Chloroform has specified as a Group 2B as a possible human carcinogen. Animal studies have shown that liver, kidney and intestines are the main target organs that could be induced to cancerous growth by chloroform exposure. Also, chloroform is known to cause reproductive and birth defects in rats and mice.

According to EPA, the Maximum Contaminant Level of 100 μg/L in drinking water is considered safe for total trihalomethane (THM) content in water (chloroform is one of the THM)

7.2 *Chlorobenzenes*

1. *Dichlorobenzenes*- these are colourless liquids. These are used as intermediates for rubber chemicals, antioxidants, dyes, pigments, pharmaceuticals and agricultural chemicals. It enters the environment, while it is used as a solvent. The major route of human exposure is through inhalation. Dichlorobenzenes causes depression of central nervous system, respiratory tract and eye irritation, anemia, skin lesions, vomiting, headaches, anorexia, weight loss, atrophy of the liver, blood dyscrasias, porphyria and chromosomal disorders in blood samples.

2. *Truchlorobenzenes*-1, 2,3 and 1,2,4- Trichlorobenzenes. Human exposure to this group of chlorobenzenes is mainly through inhalation while other routes include drinking water, food and breast milk. These compounds have the ability to damage the thyroid, liver and kidney.

3. *Tetrachlorobenzenes*- Exposure of the general population is thought to be through food. The group has the ability to damage the thyroid, lungs, liver and kidneys. Workers exposed to tetrachlorobenzenes have shown an increase in chromosomal aberrations. There is large difference in the behaviour of tetrachlorobenzene isomers. 1,2,4,5- tetrachlorobenzenes tend to remain in water and evaporates very little from it. Hence, many aquatic organisms bio-accumulate this isomer, when it is present in water.

4. *Hexachlorocyclohexane (HCH):* A pesticide still widely used in many developing countries. The technical grade comprises of five isomers-alpha, beta, gamma, delta and epsilon. The gamma-HCH referred to as Lindane has the insecticidal activity. Alpha, beta and gamma-HCHs have serious environmental impact. These isomers are very stable, persistent and lipophillic. Once introduced in the environment, they persist for years, which is more especially for the beta-isomer. Human consumption is through food, particularly dairy products, oils and cereals. The HCH moves through the food chain and gets progressively magnified while passing from one trophic level to the other. Human beings, which occupy the highest trophic level, are the sinks for these toxic chemicals. The chemical gets bio-concentrated in the breast milk and infants are exposed to concentrated amounts of the HCH pesticides.

   Chronic exposure leads to liver, lung, endocrine and other types of cancer in animals. In addition, toxic effects include shortened lifespan, lower fertility, and behavioral and reproductive changes.

7.3 *Heavy Metals*

Nickel: the metal is one of the essential metals required in extremely small quantities for normal growth and reproduction in plants and animals, including human being. However, a few nickel compounds, especially, oxides, carbonate, acetate and few more, are well known carcinogens. Metallic nickel and its alloys are listed as Group 2B- possible human carcinogens.

It has been observed that workers in nickel refining plants show higher incidence of respiratory tract cancers compared to normal populations. In nickel exposed women workers, pregnancy complication have been observed which include spontaneous abortions, higher incidence of birth malformations, musculo-skeletal and cardiovascular defects. Long-term chronic exposure to nickel has associated with chronic bronchitis and impaired lung functions.

The European Council Directive sets a maximum permissible limit of 50 μg/L nickel for human consumption.

Mercury: It is the only metal that can exist as both liquid and vapor from at ambient temperatures. Mercury is an extremely toxic with no biological functions. There are no mechanisms in the body to remove mercury once it enters the living system. Hence, the metal gets bio-concentrated and biomagnified within the food chain.

Chronic exposure of mercury affects the nervous system, causing tremors, spasms and loss of memory, severe depression, and increased excitability, delirium, hallucination and personality changes. Renal damages have been observed in chronically exposed workers.

The European Council Directive sets the maximum permissible limit of 1 μg/L mercury for human consumption.

Chromium: It is present in two chemical states. Chromium (III) is an essential trace micronutrient required for carbohydrate, protein and fat metabolism. The other, Chromium (IV) is the non-essential and the toxic form. These are corrosive and allergic to the skin. Long-term exposure, particularly air-borne chromium is associated with lung cancers. Chromium (IV) compounds are enlisted as carcinogens by the International Agency for Research on Cancer (IARC).

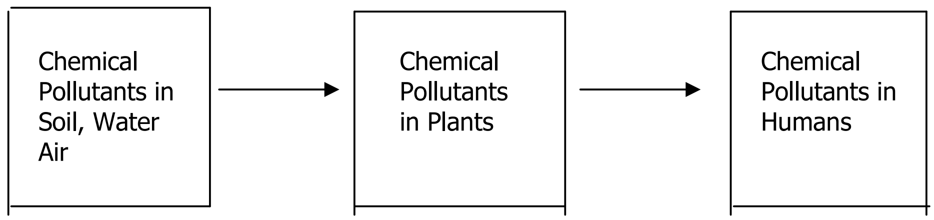
The European Council Directive sets a maximum permissible limit of 50 μg/L chromium for human consumption.

Lead: The elevated presence of Lead in our environment has been issue for decades chiefly because of lead based gasoline products. It is ubiquitous in the environment as a result, in many parts of the world, a significant level of lead turns into human body.

Ingestion of lead may pose great risks to human health. Once free in the eco-system, lead may cause nephorotoxicity, neurotoxocity and hypertension.

8. Understanding the dynamics of chemicals in the environment

When chemicals enter water and air, they are transported thousands of miles from their point of application. In places where there has been no history of chemical use, still chemicals have been detected in soil, water, animals and human. In the North Pole penguins and seals contained chemicals like DDT, Hexachlorobenzene (HCB), Persistent Organic Pollutants (POPs) and heavy metals. It is quite obvious that Eskimos would also be exposed to these xenobiotics. Similarly, water and animal samples collected from Antarctica showed a wide spectrum of chemicals that were never used in these continents.



In the Union Carbide Plant at Bhopal, the manufacture of few pesticides in addition to carbaryl (Sevin) involves the use of a wide range of chemicals followed by the release of intermediates and its final products. All these at some point of time would get released into the environment form where it would move into the three environmental sinks viz. soil, water and air and would eventually find itself entering into terrestrial ecosystems that include plants, herbivores, carnivores and omnivores (humans) or in aquatic chains.

In the manufacture of Sevin, the Union Carbide Plant at Bhopal used chloroform, carbon tetrachloride, chlorine, phosgene and a number of catalysts. In addition the UCIL manufactured formulations of sevin and aldicarb as well. The manufacture of a wide spectrum of chemicals would involve the use of a wide range of chemicals as well. The Table 6 lists the chemicals that were found in the factory premises.

Hence it is quite evident that chemicals and its intermediates depending upon its chemical structure, stability, mobility, half-life, and degradability would contaminate soil, water, air vegetation and humans.

8.1 Process of Contamination of the Ecosystem

The fate of a chemical depends upon its inherent chemical structure and its ability to react in the various environmental compartments. The three environmental compartments include soil, water and air. Chemicals once released enter either of the compartments and further movements to other compartments depend upon its chemical interaction within these compartments.

Chemicals are differentiated into persistent and non-persistent chemicals. Persistent chemicals are those that tend to remain for extremely long periods without further degradation. Hence, once such a group of chemicals are released they pose a lot of problems since these have the ability to enter from any of the other compartments to plants, animals and finally human bodies.

The non-persistent chemicals are those that biodegrade once they are released into the environment. Soil microorganisms degrade these chemicals through a process of co-metabolism into products that may or may not be toxic.

Hence, most chemicals once released into environment are dynamic and move from one compartment to the other from where these enter trophic chains and finally end up in human bodies. If chemicals are present in soil they may undergo the process of biotransformation reactions depending upon their chemical stability. The parent, terrestrial and aquatic animals and finally into human beings. Further, most chemicals undergo bio-magnification as it moves from one trophic level to the other level. Also, within the body they store and get bio-concentrated.

8.2 Waste treatment in the factory

The Union Carbide factory was in the heart of Bhopal and residential areas adjoining the factory was exposed to emissions or effluents released from the factory. All though the Air Act and Water Act existed prior to the disaster, the UCIL did not comply, as the enforcements were not taken seriously. If the factory had complied with safety norms the disaster would never have occurred. Further, after the post disaster era, chemical monitoring both by the Government and independent agencies indicated contamination within the factory premises. It is quite clear that mechanisms such as Effluent Treatment Plants (ETP) to minimize water pollution due to chemical waste were not installed.

Although evaporation ponds were present to collect chemical wastes, the possibility of overflowing during rainfall and contaminating surrounding areas was high.

8.3 Health Implications of chemical pollutants

It is extremely difficult to pinpoint the effect of a single toxic chemical since we are exposed to a wide range of chemical toxins simultaneously. Studies indicate that exposure to chemicals pollutants would show multiple effects that include fever, dairrhoea, respiratory and nervous disorders and cancer.

However, there chemical structure could be used as an invaluable tool to suggest the type of response it would elicit once it is present in the human body.

The health implications of chemicals depend entirely upon its toxicities. A few chemicals are extremely toxic and a single exposure leads to the death or exhibits toxic symptoms to an individual. The exposure of Methyl isocyanate is an example of acute toxicity. In the case of few other chemicals toxicity symptoms are exhibited due to exposure over a period of time. This happens when individuals consume food and food products or is occupationally exposed to chemicals above certain tolerance limits. Although, humans are continually exposed to a wide spectrum of toxic chemicals through food, water and air, it is only when the levels exceed Acceptable Daily Intake (ADI) create health problems.

Chemicals act upon the following systems and alter the normal physiological and biological process in the human bodies: -

1. ***Reproductive system:*** A few chemicals mimic hormones and elicit those reactions that result in the onset of female cycles. The group of chemicals is

referred to as Endocrine Disruptors. The pesticide DDT mimics the estrogen hormone and results in altering the timing of female cycles. Many chemical pollutants reduce sperm count in males.

2. ***Immune System:*** A number of chemicals alter the immune system rendering the individuals vulnerable to a host of infections. Most of the pesticides affect the immune systems. Infants and children are the most affected lot since their immune systems are still in developmental stages and most chemical pollutants inhibit immune system generating an immuno-compromised state.

3. ***Nervous System:*** Most chemical pollutants have a significant impact on the nervous system. The pollutants bring about neuro-behavioral changes. Long-term exposures result in motor neuron defects that would result in trembling of fingers, numbness, irritability and loss of memory.

4. Other effect of chemical pollutants includes genotoxicity, tertatogenicity, mutagenicity, and carcinogenicity resulting in disorders in the fetuses.

In India, the Central government had sanctioned major projects to study various aspects of the disaster. The Indian Council of Medical Research (ICMR), report was not made public. Those who had managed to get their hands to the report, found it an extremely poor designed, inferior quality research output, meant more to somehow use the grant rather than see the whole issue for the benefit of the existing survivors (see Table 2).

9. Some Previous Studies

The Indian Council of Medical Research conducted major research projects to study the impact of the gas disaster on human health (ICMR, Report – 1990,92). A total of 25 projects on human health impacts were initiated from 1985. In 1991, sixteen of these were being continued and the remaining concluded.

Table (2) A few of the projects undertaken by ICMR after the Bhopal disaster

S.No.	Name of the projects	Budget (Rupees)	Time frame	Outcome	Status
1.	Long term epidemiological studies on the health effects of toxic gas exposure through community health clinics	65,23,000.	Feb1985, and completion March 1994.	Abortion rates are still higher in exposed areas; Morbidity is still on the rise.	
2.	Studies on clinical and forensic toxicology of Bhopal Gas Disaster.	26,57,632.77	Feb 1985, till Sept 1991.	Project has been stalled because of problems between Principal Investigator and Administrative head	Recommended for continuation till March 1992 review committee.
3.	Establishment of population based cancer registry at Bhopal.	14,52,553	Oct 1985 for rupees till 1991	No evidence to suggest or rule out role of gas exposure in causation of cancer.	Recommended for continuation till March 1992 by review committee.
4	Follow up to see Corneal opacity in gas-affected areas.	22,39,167.00	March 1986 to Sept 1991.	Corneal opacity was more in affected areas.	Staff gone to court.
5	Studies on lens proteins in cataract.	9,55,566	Nov 1986 to Sept 1991	Methods not sensitive enough for studies	Extension requested
6	Studies on Broncho Alveolar lavage	2,04,110	Feb1985 to Sept 1991	Macrophagic alveolitis after 3 years of gas exposure. Cases of Chronic bronchitis is on the rise	Review committee terminated work

7	Radiological spectrum of lung chambers	17,02,53 9	Feb 1985 to Sept 1991	Pathogenic abnormalities observed	Review recommends termination
8	Chromosomal aberrations in Individuals exposed to MIC	60,67,68 0	April 1986 to Sept 1991	No results as frequent changes in Principal investigator.	Review committee recommends termination
9	Immunological parameters	31 lacs	June 1985	Most work contributed from outside the country	Review committee recommends termination
10	Mental health studies in MIC exposed population	15,44,80 0.00	Aug1985	Recovery with passage of time	Review committee recommends termination
11	Organic brain damage - a pilot study	1,49,140 .00	Dec1989 to Sept 1990	Localisation of brain damage observed	Review committee recommends termination
12.	Genetic risk evaluation on pregnancy outcomes.	35,98,22 6.00	Feb 1985 to June 1991	Sample size was too small for interpretation	Review committee terminated the work
13.	Oral, mucosal, gingival and orodental anomalies in children whose mothers were exposed	5,16,210 .00	Nov 1986 to June 1991.		Review committee asked the team to submit fresh proposal.
14	Study of pulmonary effects of toxic gases to children	23 lakhs	Sept 1985 to June 1991	Obstructive lung diseases in 15.4% in affected children as compared 8.3% control.	Review committee terminated the work

A few institutes under the Council of Scientific and Industrial Research (CSIR), for instance National Environmental Engineering Research Institute (NEERI), Nagpur and Indian Institute of Toxicological Research (ITRC), Lucknow, carried out environmental and human health. ITRC dispatched a team of experts immediately after the gas disaster as a relief team to treat the gas exposed victims. NEERI conducted environmental surveys around the UCIL premises (NEERI-Report, 1995). NEERI investigated the impact of indiscriminate disposal of wastes by UCIL on the land and water environments. The work was initiated in 1993 and the NEERI executive summary which was available on Nov. 1995, focused upon contamination in the UCIL premises and had no mention on contamination at the residential areas around the UCIL. This was only the first phase of the work, while the second phase could only begin after the Madhya Pradesh Pollution Control Board get legal permission from the court.

It is well known that Madhya Pradesh Government, had licensed the Union Carbide India Limited, and permitted it to be located within a crowded neighborhood.

In 1999, Greenpeace International carried out surveys in order to gain an insight into the nature and severity of chemical contamination (Greenpeace, 1999). Greenpeace analysed samples of solid wastes, soils and groundwater within UCIL and its surrounding areas. Greenpeace found samples to be contaminated with volatile organic compounds and heavy metals. However, the survey did not include human samples.

There is paucity of data on environmental monitoring around the areas within the factory premises of the UCIL.

Most studies focused upon health impacts and were conducted by Indian Council of Medical Research (Table 2). The Post Exposure Mortality Rates were studied by Andersen et al (1985), Patel et al, Banerji et al (1985) and Sathyamala et al (1985). In addition, studies by International Medical Commission (R. Bertell and G. Tognoni, 1996) and Long-term morbidity in survivors in the 1984 Bhopal gas survivors by P. Cullinam (1996) were published in The National Medical Journal of India.

Environmental monitoring studies included those of NEERI and IICT were done to investigate a few pollutants in the premises, contain and remediation measures to prevent further problems. However, these studies lacked follow-up studies. In addition studies by Gary Cohen, The Greenpeace studies were done to estimate levels of a few contaminant in tube-wells around the areas adjoining the factory premises and in soils within factory premise. The Industrial Toxicology Research Centre (ITRC), Lucknow has studied the impact of MIC on plants. However, no other studies were reported since then.

An organisation by the name of Bhopal Group for Information and Action (BGIA), contacted different research organisations to test the water samples, but their request was turned down since, the testing of sample, required clearance from the State government.

The Citizens Environmental Laboratory, Boston, USA agreed to test the water and soil samples from J.P. Nagar. The report indicated high levels of dichlorobenzene and phthalates in the samples. The toxicological effects of dichlorobenzene include damage to liver, kidney and respiratory system while phthalates are toxic to liver. The studies clearly indicate that there is a definite contamination problem around the residential areas surrounding the factory.

10. Current Study

The objective of the present study was to assess the extent of chemical contamination of environmental and breast milk samples around residential areas adjoining the Union Carbide Factory. The focus is on movement of chemicals from soil, water, vegetable and finally to human beings. The study would be useful indicator of chemical contamination of infants.

In the present study a few selected chemicals were chosen primarily on the basis of its extensive use in the factory and its toxic effects. For instance, chloroform a carbon tetrachloride were used in the process of manufacture of carbaryl. The heavy metal mercury was considered since it was used extensively as a sealent. Other heavy metals like chromium, nickel and lead were identified in the survey conducted by IICT. A few other chemicals were considered for analysis after running a mass-spectrum and identifying the presence of few compounds in the spectra.

None of the previous studies including those by Greenpeace have shown the movement of chemical pollutants from one level to another, through the food chain. The present study shows build-up of pollutants i.e. bioaccumulations of toxicants move from one level to another level of the food chain.

Hence, the study around residential UCIL is first of its kind to show the transfer of chemical pollutants through food chain i.e. drinking water and vegetables till it reaches the human infants via the breast milk.

There are three sinks in the environment through which chemical contaminants enter into living forms. These are soil, water and air. The soil is the major sink, followed by water that transfers contaminants through different continents while the air is responsible for a rapid long distance transmission of most of these chemicals. Further, chemical contaminants present in the different compartments can easily migrate from one compartment into another;

The soil is a niche for a diverse type of living forms from microbes to plant parts and animals. When the soil is contaminated with chemicals, it is very likely that chemical toxins transfer into the living components of the soil system. All types of living organisms that thrive in the soil, such as earthworms; plant parts such as root, tuber, bulbs, etc and further reptiles, birds and human beings are exposed to these chemicals through the food chain transfer. In case of water contamination, aquatic living forms such as mollusks (snails), fishes, amphibians, reptiles and water mammals show different levels of contaminants. Similarly, living organisms receive contaminants from atmosphere too, due to absorption, adsorption and inhalation. In the present survey, emphasis is placed tracing the links between contamination of environmental components and human being. With this in view, a pilot study was undertaken to assess the type and level of contamination in soil, water, food and breast milk around UCIL factory.

A suitable indicator for human exposure to chemical contamination is to analyse the contaminants in breast milk. The survey would not only indicate the type and levels of toxins within mothers but also show the immediate exposure of toxins to infants through breast-feed.

What exactly poisoned so many lives is still a matter of conjecture. The plant was undoubtedly manufacturing carbaryl (Sevin), a formulation of it with lindane (gamma HCH), small quantities of aldicarb (Temic) and butaphenyl methyl carbamate, all destined for use in the Indian market. However, there has been confusion surrounding the nature of the poisonous gas that took so many lives. Was the gas MIC or phosgene, or a mixture of both or some other deadly toxic gas? The examination of the residues from the faulty tank, revealed twelve compounds. These were MIC, its timer called MICT, Dimethyl urea, Trimethylurea, Trimethylbiuret, Dimethyl isocyanurate, Cyclicdione, Monomethyl amine, Dimethylamine and Trimethyl amine, HCN and Nickel salts. Interestingly, the parent carbide factory is still tight lipped about the nature of the gas.

UCIL had a large stockpile of phosgene when the disaster had occurred.

10.1 UCIL Production Process

The parent Union Carbide Corporation (UCC), West Virginia, USA, proposed the design for the plant at Bhopal, India. The UCIL manufactured the pesticide carabaryl (Sevin), (Union Carbide, Oct, 1978). In the manufacture of Sevin, two lethal compounds available- Methyl Isocyanate (MIC) and Carbonyl Chloride (Phosgene) are required. Initially, MIC was imported to manufacture Sevin, but in 1977, the UCIL plant obtained the technology for the production of MIC from the parent UCC, and by 1980 the UCIL commenced the production of MIC.

Manufacture of the carbamate pesticide, Sevin (Carbaryl).
To manufacture Sevin, there is a need to initially use three ingredients.
They are: -
1. Phosgene - ($COCl_2$)
2. Monomethylamine (MMA) - CH_3-NH
3. Methyl Isocyanate (MIC)- $CH_3N{=}C{=}O$
Phosgene also known as carbonyl chloride is manufactured by reacting chlorine with carbon monoxide. The chlorine for this reaction is brought to the plant in a tanker while carbon monoxide was produced from petroleum coke when it was made to react with oxygen. The UCIL had a facility to produce carbon monoxide.
The monomethyl amine was also brought in by a tanker, and was allowed to react with phosgene in the presence of chloroform to produce methyl carbamoyl chloride (MCC) and hydrogen chloride gas. The process is called phosgenatation.
The methyl isocynate (MIC) is produced when Monomethylamine (MMA) is heated.
An Overview of the chemical reactions are: -

1). $COCl_2$ + CH_3NH_2 ------------ $CH_3NHCOCl$ + HCl + Heat
Phosgene MMA MCC Hydrogen Chloride
In step 1, the reaction proceeded in the presence of chloroform ($CHCl_3$).

2). $CH_3NHCOCl$ ----------------- $CH_3N{=}C{=}O$ + HCl
MCC MIC
The MIC was collected and stored in stainless steel tank while the remaining HCl, Chloroform were collected recycled for use once again.

3). $CH_3N{=}C{=}O$ + alpha napthol --------------- * $OCONHCH_3$ Carbaryl (Sevin)
In step 3, the reaction proceeded in the presence of carbon tetrachloride (CCl_4).

Note: The MMA and chlorine gas was brought in by tank truck from other parts of India and stored in tanks and used whenever MIC was needed to produce Sevin

Other pesticides: Although Sevin was the major pesticide; smaller amounts of other carbamate pesticides were also manufactured using MIC. These were aldicarb (Temic) and butyl phenyl methylcarbamate and a formulation of Sevin-lindane was also made at UCIL.

10.2 Limitation of the present study

The environment survey around adjoining residential areas around UCIL shows substantial evidence of chemical contamination. The present study although undoubtedly indicates extensive chemical pollution, however increasing sample size and sample types could highlight chemical pollution by showing translocation at various levels of the food chain. For instance a link between soil – earthworm – birds (including chickens) could establish how birds were getting poisoned and its possible linkage to humans; similarly aquatic food chains involving water and aquatic organisms like Daphania, mussels and fish and humans could have given transfer in a more sequential pathway. Here, the link between soil, ground water, vegetables and human breast milk has been established. The increase in sample size would also enable incorporation in statistical analysis to show correlation between different pollutants with respect to different sample types. Hence the present study lacks diverse sample types and sample numbers. The paucity of funds in the present study in responsible for reducing sample size and types.

10.3 Future study for assessment

The present study has indicated without any doubt the chemical contamination of human samples. It would be essential now to continue studies on epidemiological surveys and chromosome analysis. It would be worthwhile to study the chromosome aberration in children born after the Bhopal gas tragedy.

11. Survey on Human and Environmental Contamination around UCIL.

The most important task prior to assessment of human and environmental contamination would to be scrutinise the UCIL's inventory for toxic chemicals. Ascertain if, few of these chemicals they would still exist in the environment.

The fate and behaviour of a chemical in an environment is its intrinsic property. It depends upon the constituting elements and the bonds that exist between them and the nature. The physical property like solubility, volatility, boiling point, melting point as well as chemical properties such as reactions in air, water and in different environmental factors depends upon the intrinsic property, characteristic to it.

The UCIL inventory indicates a wide spectrum of compounds that were reactants, catalysts, byproducts or the end products. It would be a futile task to test for each of them since; many would not be present because of their short half-lives or would be transformed into other harmless products by natural environmental conditions. It would be worthwhile to consider those chemicals, which are toxic and also persistent i.e., remain over long periods of time in the environment.

In the present environmental and human contamination survey, the presence of a few Heavy metals, Pesticides and Volatile Organic Carbons (VOC's) in samples were investigated.

1. Heavy metals: A total of four heavy metals were tested in the samples. These are
a). Mercury (Hg)
b). Lead (Pb)
c). Chromium (Cr)
d). Nickel (Ni)

2. Pesticides: HCH (BHC) isomers, like gamma-HCH (Lindane), alpha- HCH, beta-HCH were considered.
Note: Sevin (carbaryl) and Temic (aldicarb) were not considered because of their short half-lives in the environment.
3. VOC's: Dichiorobenzene, 1,3,5-trichlorobenzene, 1,2,4-trichlorobenzene, 1,2,3-trichlorobenzene and tetrachlorobenzene.
4. Halo-organics: Chloroform and Dichloromethane

The factory started operating from 1969 and till 1977 it used dump all effluents in an open pit near the eastern wall of the factory. Then onwards most but not all, effluents used to be discharged into the two solar evaporation ponds (SEP), behind and outside of the factory. The solar evaporation ponds were spread in an approximate area of 22 acres. The lime pit effluents and other organic wastes were discharged into the evaporation ponds. The evaporation ponds were lined with a film of polythene to prevent seepage. However, one should not overlook the fact that polythene sheet are not corrosive proof and a wide spectrum of chemicals present in the effluents, like acids can easily destroy their structure.

The UCIL had two lime pits 28 feet in length X 12 feet breath X 12 feet D* each having two compartments. The primary neutralisation pit of a size 22 feet X 12 feet X 12 feet and the secondary neutralization pit of 6 feet X 12 feet X 12 feet were separated by a concrete wall. Hydrochloric acid is pumped to the lime pit for neutralisation and the effluents from here go to the evaporation pond. Although, the

UCIL management insists that the spent lime is replenished, that after every time acid is neutralised, some lime is used up in the process, this cannot be ascertained.
In rainy season, these effluents used to overflow and enter into sewages that used to pass through J.P. Nagar, a slum cluster opposite the main gate of the factory.
It has been 17 years since the closure of the factory, but still the hand pump and the community water have a strong stench of organic solvents.

11.1 Chemicals dumped within the factory premises.

The UCIL workers with more than 10 years experience of working in the factory reported that the following chemicals (Table 3) have been dumped within the factory premises by the factory management.

Table 3: Chemicals dumped in the factory site.

Chemical	**Use**	**Dumped amount in MT**
Alpha-napthol	As slurry and dust	50.00
Chloroform	Solvent in MIC plant	100.00
Carbon tetrachloride	Solvent in Sevin plant	200.00
Methanol	Solvent in Temic plant	10.00
Methylene chloride	Solvent in Temic plant	50.00
Mercury	Sealant in Pan filter	1.0
Ortho-dichlorobenzene	Solvent in Napthol plant	250.00
Sevin	As slurry and dust	50.00

In April, 1996, the Indian Institute of Chemical Technology (IICT), Hydria and National Environmental Engineering Research Institute (NEERI), Nagpur, presented their report on the basis of analysis of 2.5 kg sample collected from drums, bags and trolleys near cycle stand godown and soap stone godown.

Table 4: Metals detected in Sevin and alpha-napthol waste*

Metals	Sevin waste (mg/Kg)	Alpha-napthol waste (mg/Kg)
Cadmium	1.247	Below detection limit
Chromium	26.8	42.3
Copper	40.64	7.35
Lead	22.26	4.88
Manganese	487.25	67.66
Nickel	20.85	31.44
Zinc	28.73	17.05

Table 5: Organic chemicals detected in sevin and napthol tar*

Organic chemicals	Sevin tar (mg/Kg)	Napthol tar (mg/Kg)
Volatile matter	3.07	2.83
Napthol content	12.1	23.18

* Analyses conducted by Indian Institute of Chemical Technology (IICT), Hyderabad.
It is worthwhile to mention that none of the analytical surveys conducted post Bhopal disaster, have shown the presence of the pesticides like Sevin and aldicarb were the final products of the factory. Both, carbaryl and aldicarb is non-persistent

compound, unlike organochlorines such as DDT and BHC (HCH), and have short half-lives in the environment. Hence, testing for these chemicals would be a futile exercise unless data for this and a few other chemicals had been made available before the disaster (see Table 6).

Table 6: Chemicals dumped by Union Carbide Management around the factory from 1969-84.

S.No.	Chemicals	Quantity (MT)	Use in factory	Nature of pollution
1.	Aldicarb	2.0	Product	Air, water & soil
2.	Alpha-napthol	50.0	Ingredient	Air & Soil
3.	Benzene Hexachloride	5.0	Ingredient	Air, water & soil
4.	Carbaryl	50.00	Product	Air, water & soil
5.	Carbon tetrachloride	500.00	Solvent	Air & water
6.	Chemical waste tar	50.00	Waste	Water & soil
7.	Chlorobenzoyl chloride	10.00	Ingredient	Air, water & soil
8.	Chloroform	300.00	Solvent	Air & water
9.	Chlorine	20.00	Ingredient	Air
10.	Chlorosulphonic acid	50.00	Ingredient	Air & soil
11.	Hydrochlroic acid	50.00	Ingredient	Air & soil
12.	Methanol	50.00	Solvent	Air & water
13.	Methylene chloride	100.00	Solvent	Air & water
14.	Methyl Isocyanate	5.0	Ingredient	Air, water and soil
15.	Mercury	1.0	Sealant pan filter	Water and soil
16.	Monochloro toluene	10.00	Ingredient	Air, water and soil
17.	Monomethyl amine	25.00	Ingredient	Air
18.	Naphthalene	50.00	Ingredient	Air
19.	Ortho dichlorobenzene	500.00	Solvent	Air
20.	Phosgene	5.0	Ingredient	Air
21.	Tri methylamine	50.00	Catalyst	Air
22.	Toluene	20.00	Ingredient	Air, water & soil

Source: Satinath Sarangi, Sambhavana Clinic, Bhopal

The factory became operative in December 1969 and since then till 1984, a major amount of chemical substances like pesticides formulated in the factory, initial reactants, byproducts, catalysts and other substances used, were dumped in and around factory premises. These toxic contaminants in the form of solid, liquid and gaseous products caused pollution in the soil, water and air in and around the factory. Till date, the soil and water around the factory are polluted.

11.2 Dumping of chemicals.

Many toxic chemicals are still remained dumped within the UCIL factory site (see photograph) while others are dumped at the solar evaporation pond (see photograph) that is across the railway track. The UCIL had acquired land for the purpose of a landfill that lay across the railway track. It is understood that toxic wastes were pumped from the factory to this landfill. In fact, this waste dump is present in the other side of the railway track, across the factory. To pump the effluents, it would require pipes to be laid under the railway track, which means it has to be done with prior permission of the railway ministry and technically unfeasible to put anything under the railway track.

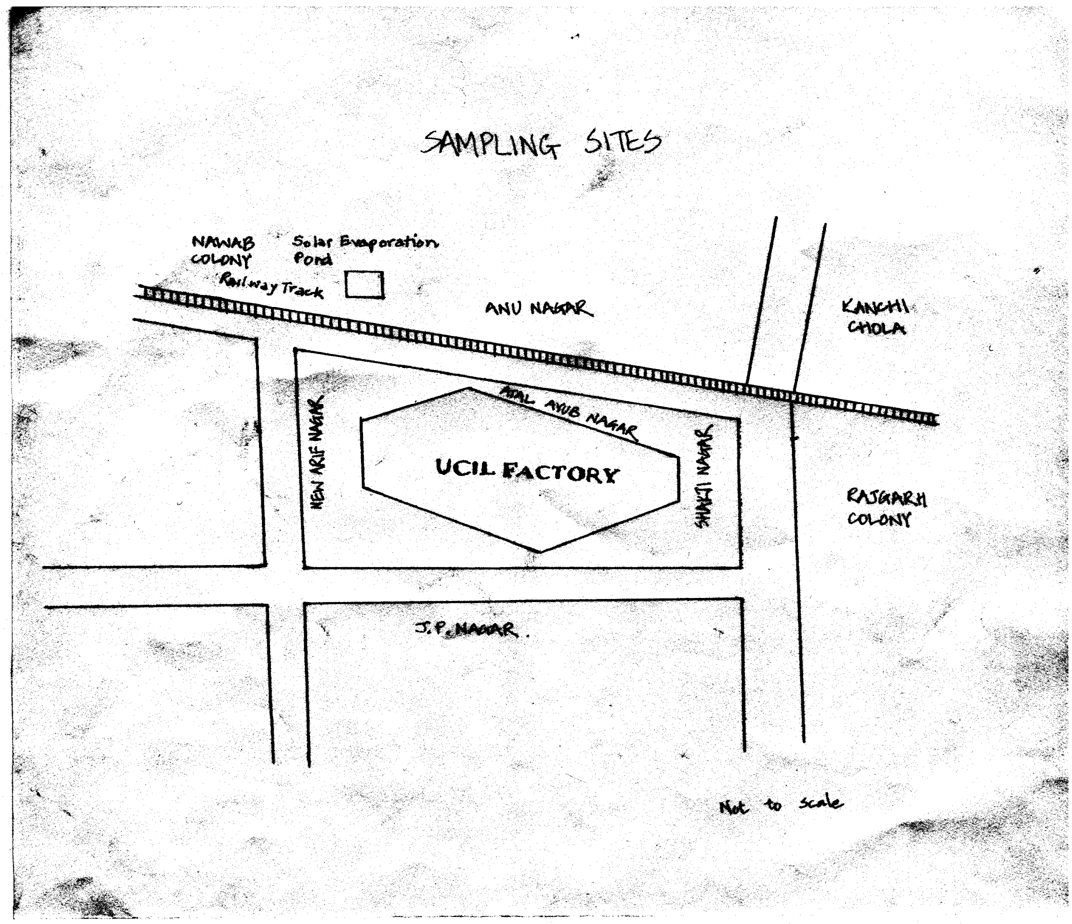
12. Materials, Methods and Results

12.1 *Sampling sites.*

The sampling sites were selected on the basis of their proximity to the UCIL factory and the dumpsites near the factory. In addition, different directions were also selected for sample collection to know the spatial variations in contamination (see figure - 2).

The following sites were selected in the residential areas:

1). J.P. Nagar. 2). Kanchi. 3). Nawab colony. 4). Atal Ayub Nagar
5). Anu Nagar. 6). Arif Nagar. 7). Ramgarh Colony. 8). Factory premises



12.2 *Samples.*

In order to investigate the environmental transfer of a chemical toxin, it would be imperative to first detect and quantitate a few of these suspected chemical toxins in the environment and then ascertain if there is a route for human exposure.
In this study, the following samples were tested for contamination: -

1). Soil: The levels in the soil would indicate availability of chemical toxins for living forms of the soil.
2). Water: Its contamination further indicates the easy transfer of chemical toxins to life forms, depending upon the particular water.
3). Food samples: Chemical toxins are absorbed from soil in to vegetables grown in contaminated areas and thus becomes a contaminated link in the food chain.
4). Breast milk: - Contaminant levels indicating toxins present, which can pose danger to next generation.

12.3 *Sample Collection.*

Soil samples: A total of 14 samples were collected for the analyses, out of which 5 samples were from the factory site, while the remaining from the residential areas surrounding the factory site.

The residential areas include Anu Nagar and Nawab colony at the northern side of the factory, Atal Ayub Nagar at the northwest; Kanchi at the northeastern side; J.P. Nagar at the southern side; Rajagarh colony at the eastern side and Shakti Nagar at the south eastern side.

The soil samples from the factory premises include two samples very close to the Sevin plant side, one from the cycle stand site, one close to the alpha napthol plant site and one from the solar evaporation tank which lies across the railway track.
The collections were based on random sampling method where five core sub-samples i.e. from four corners and a central point of a selected site represented a sample for a given area. An auger was introduced 3 inches deep from the surface of the soil to collect the soil sample from each sampling point. All soil samples were collected in transparent polythene bags, labeled and sent to the place of analyses. These samples were stored at -20° C, until extraction for contaminant was done.

Water samples: A total of eleven water samples were collected from the same areas of soil collection. In residential areas, water sample were collected from hand pumps used by the local population for drinking, bathing and washing purposes. The water samples were collected in Teflon capped 2.5 L brown bottles, to minimize the photolyis of light sensitive compounds in the water samples. In addition, water samples were also collected within the factory premises i.e. within the Sevin plant area and from an open pond adjacent to the solar evaporation pond. Samples were transported to the laboratory, and stored in a deep freezer maintained at -20° C.

Food samples: In one of the residential areas, local population grows seasonal vegetables for their consumption. These include radish, brinjal and palak and methi (spinachs). Samples of vegetables were wrapped in foil and sent to the laboratory, where it was stored at -20° C.

Breast milk: A total of eleven milk samples were collected from residential areas adjoining the UCIL factory. All relevant details of the donor like age, number of previous deliveries, socio-economic conditions, etc were collected prior to collection of the samples.

Samples of breast milk were manually collected in 5ml Teflon screw cap Borosil vials and stored immediately at 0° C and transported in an ice box to the laboratory to keep at -20° C until extraction of contaminants was done.

Note: The most difficult part of the survey was the collection of breast milk samples. All efforts at three major government hospitals to acquire breast milk samples proved futile, since, according to the medical superintendent, the government had given strict instructions not to permit any individual/s or from private institutions, other than government agencies, to collect samples related to Bhopal gas disaster. Mr. Sathyu Sarangi, from the Sambhavana Trust provided the milk samples with help of his staff.

13. Chemical Analysis of Samples

13.1 Metals

The sample preparation depends to a large extent on the sample, its matrix and sample treatment which finally determines the accuracy of the procedure. All the samples were thawed prior to extraction. The analysis of metals from the sample, involves sample drying, digestion, extraction and finally the analysis.

Sample drying: Soil samples were dried prior to weighing and dissolution. Air-drying at room temperature was done for soil as substantial loss of volatile elements, such as mercury can occur at elevated temperatures. The water samples (10 ml.) were taken as such without further processing. The plant materials were dried at 80°C till the complete drying as per standard recommended procedures for plant materials.

Digestion and Extraction: The total element in the sample requires complete and vigorous digestion with acids (Aqua regia a mixture of Nitric acid and Hydrochloric acid at a ratio of 3:1) for soil samples. For the soil difestion and extraction of metals 0.1 gm of the sample was mixed 5 ml Aqua regia. The mixture was heated on a hotplate for 30 minutes, and later cooled and filtered. This final volume is made up to 100 ml in a standard flask.

In the case of plant materials, the most satisfactory and universal digestion procedure adopted is the use of concentrated HNO_3 for digestion.

The breast milk samples were totally dried, using a lyophilizer (this process milk is totally dried) used to make infant formulae and later 0.2 gm of the sample was dissolved in 5 ml of dilute HCl and the mixture was heated for 20 minutes and filtered through Whatman no 42 filter paper. This 2000 ppm solution was used for actual analysis. The results are reported for 1000 ppm.

Analysis: The analysis was carried out in a Perkin Elmer model Inductively Coupled Plasma Spectrometer (ICP-OES).
In the present survey, Inductively Coupled Plasma Spectrometer (ICP-OES) carried out the analysis of Chromium (Cr), Nickel (Ni), Mercury (Hg) and Lead (Pb) directly from the extract solution.

Standard preparation: Commercial standards of 10000 ppm concentration from Perkin Elmer were purchased. Multi element standards for ICP-OES analysis were freshly prepared keeping in mind that the elements to be analysed are compatible and are grouped together to avoid precipitation in the mixed solution.
Operating conditions for aqueous solutions: Machine used Integra XL single and dual monochromator. The Integra XL is a fully computerized Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

Table 7: The operating conditions of ICP-OES.

ICP - OES.	Specifications
Power	1000 Watts
Nebulizer type	Concentric
Plasma gas flow	10 l/min
Auxiliary gas flow (Argon)	0.7 l/min
Sample gas flow	0.4 l/min
Viewing height	8.0 mm
Pump speed	9.0 rpm

Results

Among the four heavy metals analysed in the soil samples, nickel was the most prevalent one. Five of the six soil samples showed nickel contamination, while chromium, mercury and lead were present in three each and two samples, respectively. The table 8 indicates the concentration of heavy metals in the soil samples collected from residential localities.

Table 8: Concentration (mg/L) of heavy metals in soil samples in residential samples around UCIL factory, Bhopal.

Location	Chromium	Nickel	Mercury	Lead
Anu Nagar	-	1.628	0.9798	-
Atal Ayub Nagar	-	-	2.429	-
J.P. Nagar	1.131	0.2143	-	0.4667
Kanchi Chola	0.7845	0.5779	-	-
Nawab Colony	1.958	2.3700	-	-
New Arif Nagar	-	1.3990	1.2650	0.3533

The soil samples in the UCIL factory were analysed from four different sites, as different types of chemicals reactions were confined to different areas within the factory. Soil samples mostly showed the presence of chromium and nickel.
Mercury was detected in higher levels in the samples collected from the alpha-napthol site and below the Pan filter site. Nickel was present in four of the five sites within the factory premises, while mercury was present in two sites at almost similar quantities, but their levels were comparatively high. The table 9 indicates the concentration of heavy metals in the soil samples collected from the premises of the factory.

Table 9: Concentration (mg/L) of heavy metals in soil sample within the UCIL factory.

Location	Chromium	Nickel	Mercury	Lead
Pan filter area	-	1.1090	1.8160	-
Sevin Cycle shed	0.0206	4.7660	-	-
Sevin Plant - Outside - 1	0.1520	3.9350	-	-
Sevin Plant - Outside - II	-	4.6820	-	-
Alpha-napthol plant site	-	-	1.8980	-
Solar Evaporation Pond	0.5269	0.0065	-	0.2767

Among the ten ground water samples collected from the residential areas, all samples contained chromium and nickel, while mercury was present in six and lead in eight water samples. Nickel was the predominant contaminant in water, with an average of 1.0990 ppm, followed by mercury, chromium and lead whose average levels were, 0.567, 0.026 and 0.122 ppm, respectively. The table 10 indicates the concentration of heavy metals in the ground water samples.

Table10: Concentration (mg/L) of heavy metals in hand pump water

Location	Chromium	Nickel	Mercury	Lead
Anu Nagar Hand pump - 1	0.0056	0.9036	0.2576	-
Anu Nagar Hand pump - 2	0.0107	0.7804	0.2939	0.0013
Atal Ayub Nagar	0.0117	1.8750	-	-
J.P. Nagar Hand pump - 2	0.0149	0.7447	-	0.0497
Kanchi Chola	0.0210	0.9417	-	0.0548
Nawab Colony	0.0095	1.8000	-	0.0117
New Arif Nagar	0.0057	1.0800	0.1197	0.0398
Rajgarh Colony	0.0143	0.7932	0.0264	0.0413
Solar Evaporation Pond- Pond Water	0.0116	0.1861	0.0343	0.0321
Shakti Nagar	0.0126	0.7155	0.0317	0.0113

All the three vegetable samples grown at J.P. Nagar, showed chromium and nickel, while palak showed chromium, nickel, mercury and lead. The levels of heavy metals were found highest in palak than any other vegetables. The table 11 indicates the concentration of heavy metals in the vegetable samples collected from J.P. Nagar site.

Table11: Concentration (mg/Kg) of heavy metals in a few vegetable samples grown at a residential area opposite to the UCIL factory (J.P. Nagar)

Vegetables	Chromium	Nickel	Mercury	Lead
Brinjal	0.1541	0.3869	-	-
Radish	0.1130	0.1169	-	-
Palak	1.1370	1.2840	2.5100	0.5733

The predominant metal detected in the breast milk samples was lead, which was found in seven of the eight samples analysed. Chromium was absent in the breast milk, while nickel and mercury were present in two and three samples, respectively. The mean levels of lead were marginally higher than mercury, although mercury was detected in fewer samples compared to lead. The table 12 indicates the concentration of heavy metals in the breast milk samples.

Table 12: Concentration (mg/L) of heavy metals in breast milk samples collected from residential areas adjoining UCIL factory.

Location	Chromium	Nickel	Mercury	Lead
Atal Ayub Nagar	-	-	-	0.0380
J.P. Nagar	-	0.0581	0.0550	-
J.P.Nagar	-	-	-	0.0454
J.P. Nagar	-	-		0.0801
Kanchi Chola	-	-	0.0550	0.3135
New Arif Nagar	-	-	-	0.1517
Rajgarh colony	-	-	0.6665	0.0643
Shakti Nagar	-	0.5235	-	0.2830

13.2 Chlorinated Compounds.

Pesticide analysis was carried out through a Gas-Chromatograph (GC), (Perkin Elmer Autosystem XL). Each sample was analysed twice and the reproducibility of results was almost 90% by the above methods. Recovery studies were performed separately for two soil samples and the results showed recoveries exceeding 90% for all the twelve pesticides. Recovery percentage for HCH was around 87-90%.
The pesticides chosen for study were obtained from RDH Laborchemikalien GmbH & Co. KG D-30918 Seelze via Promochem India Pvt. Ltd, Bangalore India. β-BHC was 99% pure and all the other pesticides were above 99.6% purity level.

The following organochlorine pesticides were analysed.

1. Beta- BHC (1,2,3,4,5,6-hexachlorocyclohexane)
2. Gamma- BHC (1,2,3,4,5,6-hexachlorocyclohexane)
3. Dichlorobenzene
4. Trichlorobenzenes 1,2,3-, 1,2,4-, & 1,3,5- Trichlorobenzenes.
5. Tetrachlorobenzenes
6. Chloroform
7. Dichloromethane

Temperature programming of GC:
1. BHC: 220 to 270°C at a ramp of 2°C per minute

2. Chlorinated compounds: 40 to 70°C at a ramp of 2°C per minute,

Soil

For the pesticide analysis, each soil sample size taken was approximately 500g, out of which representative sub-samples in triplicate (35g) were randomly taken for the analysis. The pesticides were extracted for 8-10 hrs at the rate of 4-5 cycles per hour, in 150 ml of 50%(v/v) acetone in hexane in a Soxhlet extractor (Thao et al.1993b, EPA method 3540). The extract obtained was cooled, filtered and concentrated in a rotary evaporator. The concentrate was again extracted in hexane/water with the help of a separating funnel and dehydrated by passing through sodium sulphate. The solution thus obtained was filtered and concentrated to approximately 5ml. The fractions obtained on with 20%(v/v) dichloromethane in hexane were analysed for the presence of twelve pesticides by GC equipped with a split – split less injection port and selective electron-capture detector (ECD). This detector allows the detection of contaminants at trace level concentrations in the lower ppb range in the presence of a multitude of compounds extracted from the matrix to which these detectors do not respond. The column used was PE-17, length 30m, ID 0.25mm, and film 0.25mm with a 2ml/min flow. The carrier gas and the makeup gas was nitrogen employing the split mode. The oven temperature was kept at 190°C to 280°C with a ramp of 5°C/min. The samples were calibrated (retention time, area count) against 1 to 10 ppm standard solutions of all twelve pesticides. Each peak is characterised by its retention time and the response factors in ECD. Sample results were quantitated in ppm automatically by the GC software. The detection limit was 0.001 mg/Kg for organochlorine and 0.01 mg/Kg for organophosphate pesticides.

Recovery studies were performed separately for three original sample types by spiking the samples with known quantities of different pesticides and subjecting them to similar analytical procedures. The average recovery was almost 92.8% for organochlorines and 89.1% for organophosphates. The reproducibility of results for all the pesticides was 95.8% and above for all the samples. However, the mean average reading of a particular type of sample analysed in duplicate, was considered. One GC injection (30 min) of 5μl covered all twelve pesticides included in the analysis. Hamilton micro syringe injection of the pesticide dissolved in hexane as solvent were made directly onto the coated silanized column solid support, thereby eliminating the possibility of catalytic degradation by metallic surfaces. Pesticides were identified according to their retention times. The actual relative retention times for the different pesticides were compared with unknown samples. The multi-residue method that can detect twelve pesticides in one analytical run was preferred. This method is characterised by a broad scope of application, good recoveries and sensitivity and low solvent consumption, coupled with good analytical quality control.

Milk, Water and Vegetable extraction

Weighed milk sample was extracted with 5-6 drops of 10% Sodium chloride solution and 15% Dichloromethane (DCM) in hexane. Organic layer was collected and the aqueous layer was extracted twice. The three organic layers were mixed and sodium sulphate was added to it, filtered and evaporated the solvent. In order to evaporate the residual DCM, some hexane in the RB was added and evaporated twice. Finally the volume was made to 5 ml with n-hexane. Pesticides in milk and vegetable were extracted by the method followed by Kumari and Kathpal, 1995; Nair et al, 1996 and Madan et al, 1996.

Results

The total HCH (BHC) pesticide concentrations in the six soil samples were 9 mg/Kg. The average value of its concentration was 1.60 ppm. Among the six residential areas, J.P Nagar had the highest level of the pesticides HCH with a level of 5.038 mg/Kg, while Nawab Colony, Atul Ayub Nagar had almost similar levels, exceeding slightly over 1 ppm. Among the HCH isomers, the proportion of gamma- HCH exceeded those of beta- HCH. The table 13 indicates the concentration of pesticides in residential areas around the factory.

Table13: Pesticide HCH (BHC) in soil samples (mg/Kg) around residential areas adjoining UCIL factory premises.

Location	Beta – HCH	Gamma –HCH
J.P. Nagar	0.2263	4.812
Kanchi	0.3697	0.2208
Nawab Colony	0.0555	1.7181
Atal Ayub Nagar	0.0014	1.0633
Anu Nagar	0.0180	0.0770
New Arif Nagar	0.0404	1.0265

Among the four sites in the factory premises, the HCH levels were highest at the Sevin Shed. The total HCH in this area was slightly over 8 mg/Kg, which was five times more than those present in Sevin plant site-I. The Solar Evaporation Pond, which was dumping site outside the premise showed very low levels of the HCH isomers. Table 14 indicates the concentration of pesticide HCH in the factory premises.

Table 14: Pesticide HCH (BHC) in soil samples (mg/Kg) within UCIL factory premises.

Location	Beta – HCH	Gamma -HCH
Sevin Shed	0.0035	8.2814
Sevin Plant - I	0.3101	1.3777
Sevin Plant - II	0.0897	0.0359
Alpha-Napthol Site	0.0041	0.0663
Solar Evaporation Pond *	Nil	0.0358

* Acquired by the UCIL factory outside the premises of the factory

The total levels of HCH isomers in Brinjal and Palak were almost similar. The gamma-HCH isomer exceeded those of beta-HCH isomer. Table 15 indicates the pesticide HCH in vegetable samples grown close to the UCIL premises.

Table15: Pesticide HCH (BHC) in vegetable samples (mg/Kg) around residential areas adjoining UCIL factory premises.

Vegetables	Beta- HCH	Gamma- HCH
Brinjal	0.0033	0.0294
Palak	Nil	0.0215

The total concentration of the pesticide HCH in the ground water samples from the residential areas was 0.0898 mg/L. The mean level detected in water was 0.011 ppm. Water samples from Anu Nagar and Shakti Nagar were most contaminated with the pesticide HCH, while the other areas had almost similar levels. Table 16 indicates the pesticide HCH in ground water samples adjoining the UCIL factory premises.

Table 16: Pesticide HCH (BHC) in groundwater samples (mg/Kg) around residential areas adjoining UCIL factory.

Location	Beta – HCH	Gamma -HCH
Anu Nagar - II	0.0256	0.0146
Atal Ayub Nagar	0.0016	0.0011
J.P. Nagar	0.0003	0.0015
Kanchi Chola	0.0005	0.0027
Nawab Colony	0.0001	0.0012
New Arif Nagar	0.0016	0.0014
Rajgarh Colony	0.0005	0.0004
Shakti Nagar.	0.0336	0.0031

The water tested from the factory premises showed 0.115 mg/Kg of the pesticide HCH. This level is ten times more than those present in the residential areas around the factory. Table 17 indicates the pesticide HCH (BHC) in water samples within the UCIL premises.

Table 17: Pesticide HCH (BHC) in water samples (mg/L) from the UCIL factory premises.

Location	Beta – HCH	Gamma -HCH
Sevin Plant Site	0.1050	0.0104
Solar Evaporation Pond – Water*	0.0010	0.0175

* Acquired by the UCIL factory outside the premises of the factory

All samples of breast milk showed the presence of pesticide HCH. The average level of the pesticide in the breast milk was 2.39 mg/Kg while the levels ranged from 0.179 to 11.44 mg/Kg. The breast milk sample from Shakti Nagar had highest levels for both beta and gamma – HCH when compared to the other samples. Table 18 indicates the level of pesticide in breast milk samples from the UCIL factory premises.

Table 18: Pesticide HCH (BHC) in breast milk samples (mg/L) in residential areas around the UCIL Factory.

Location	Beta - HCH	Gamma -HCH
Shakti Nagar	5.1367	6.3345
Kanchi Chola	0.0376	0.1414
Rajgarh Colony	0.1912	0.0915
J.P.Nagar	0.6947	0.0154
New Arif Nagar	0.0684	1.3580
J.P.Nagar	0.3271	0.6388
J.P.Nagar	0.0232	0.2343
Atal Ayub Nagar	0.2317	0.1160

13.3 Volatile Organic Compounds (VOC's)

Among the residential areas, J.P. Nagar showed the highest contamination of Volatile Organic Compounds (VOC's) followed by Kanchi Chola, which showed 7.5 times lower than that of J.P. Nagar. Dichlorobenzene was the predominant contaminant in most of the cases. The total VOC level found in the soil samples were 5.86 mg/Kg while their average was slightly lower than 1 mg/Kg. Among the six soil samples, Dichlorobenzene, 1,3,5-Trichlorobenzene and Tetrachlorobenzene were present in all the samples. Table 19 indicates the VOC's in soil samples adjoining the UCIL factory premises.

Table 19: Volatile Organic Compounds (VOC's) in soil samples (mg/Kg) in residential areas around UCIL.

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
J.P. Nagar	2.4961	0.7447	0.6070	0.1701	0.1073
Kanchi	0.1096	0.4149	0.0156	Nil	0.0053
Nawab Colony	0.1304	0.1678	0.0063	Nil	0.0060
Atal Ayub Nagar	0.1294	0.0102	0.0127	0.0117	0.0339
Anu Nagar	0.1419	0.0135	Nil	Nil	0.0161
New Arif Nagar	0.1637	0.0140	0.0150	Nil	0.0463

Both the vegetables were found to contain VOCs. The dichlorobenzene was the predominant contaminant in the samples. The mean concentration of VOCs in the vegetable samples was found to be 0.132 mg/Kg. The concentration of VOC's was almost similar in both the vegetable samples analysed. Table 20 indicates the VOC's in vegetable samples collected adjoining the UCIL factory premises.

Table 20: Volatile Organic Compounds (VOC's) in vegetable samples (mg/Kg) in residential areas around UCIL.

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
Brinjal	0.2653	0	0.0082	Nil	0.0124
Palak	0.2354	0	0.0073	Nil	Nil

All the soils tested for VOC's in the UCIL factory showed positive results. All the soils from the factory site showed Dichlorobenzenes, 1,3,5-Trichlorobenzenes, 1,2,4-Trichlorobenzenes and Tetrachlorobenzenes. Among the four sample sites, the Sevin Shed showed the highest concentration of VOC's. The amounts of VOC's at the other three sites were more or less similar. The total VOC content in the samples were 1.855 mg/Kg while the mean levels in the factory premises was 0.463 mg/Kg. The total VOC content in soils from the Solar Evaporation Pond was found to be 0.268 mg/Kg. Table 21 indicates the VOC's in soil samples from the UCIL factory premises.

Table 21: Volatile Organic Compounds (VOC's) in soil samples (mg/Kg) in the UCIL

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
Sevin Shed	0.1613	0.1974	0.0065	Nil	0.4711
Sevin Plant-I	0.1292	0.1883	0.0044	Nil	0.0233
Sevin Plant –II	0.1124	0.2143	0.0073	Nil	0.0046
Alpha Napthol Site	0.1212	0.2081	0.0056	Nil	Nil
SEP –Soil	0.1215	0.1389	0.0074	0.0006	Nil

The concentration of VOC's was highest in Kanchi Chola, while a marginally lower level was found in Anu Nagar. In the other areas, it was almost two to ten times lower than these areas. The mean concentrations of VOC's in the ground water samples of the residential areas were found to be 0.050 mg/Kg. Table 22 indicates the VOC's in ground water samples from the UCIL factory premises.

Table 22: Volatile Organic Compounds (VOC's) in groundwater samples (mg/Kg) in residential areas around UCIL.

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
Anu Nagar	0.0104	Nil	Nil	Nil	0.0007
Atal Ayub Nagar	0.0008	Nil	Nil	Nil	0.0007
J.P.Nagar	0.0094	Nil	Nil	Nil	0.0002
Kanchi Chola	0.0147	Nil	Nil	0.0002	Nil
Nawab	0.0012	Nil	Nil	0.0003	0.0006

Colony					
New Arif Nagar	Nil	Nil	0.0029	Nil	Nil
Rajgarh Colony	Nil	Nil	0.0015	Nil	0.0002
Shakti Nagar	Nil	Nil	0.0060	0.0001	0.0005

Water samples from the factory premises contained 0.0331 mg/L VOC's while those from a water pond adjacent to the Solar Evaporation Pond contained 0.008 mg/L VOC's.

Table 23: Volatile Organic Compounds (VOC's) in water samples (mg/L) from the UCIL factory premise.

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
Sevin Plant-ditch	Nil	Nil	0.0025	0.0008	0.0298
S.E.P	Nil	Nil	0.0058	0.0002	0.0007

All samples of breast milk contained VOC's. The total VOC content in breast milk samples was 17.12 mg/Kg. The 1,3,5 Trichlorobenzene was the predominant VOC and was present in all the samples. The sample from Shakti Nagar contained 9.52 mg/L and VOC was highest when compared to other samples. The average level of the VOC in the breast milk was 2.85 mg/Kg while the levels ranged from 0.588 to 9.52 mg/Kg. Table 24 indicates the VOC's in breast milk samples from the UCIL factory premises.

Table 24: Volatile Organic Compounds (VOC's) in breast milk samples (mg/L) in residential areas around UCIL.

Location	Dichloro-benzene	Trichloro-benzene (1,3,5)	Trichloro-benzene (1,2,4)	Trichloro-benzene (1,2,3)	Tetrachloro-benzene
Shakti Nagar	2.2693	0.6226	5.8984	0.4690	02573
Kanchi Chola	Nil	1.5986	0.4120	Nil	0.0386
Rajgarh Colony	0.4580	0.2041	Nil	0.1354	0.0601
J.P.Nagar	0.3380	0.1993	Nil	Nil	Nil
New Arif Nagar	Nil	2.1718	0.7450	Nil	0.1094
J.P.Nagar	0.5221	0.1800	Nil	Nil	0.0473
J.P.Nagar	0.3514	0.0369	Nil	0.0327	0.0574
Atal Ayub Nagar	0.7016	0.3826	Nil	Nil	Nil

13.4 Halo-organics: Dichloromethane and Chloroform.

Among the six soil samples from the residential area, Dichloromethane was present in all the samples. The levels ranged from 0.082 to 0.170 mg/Kg with an average amounting to 0.103 mg/Kg. The soil samples from Kanchi Chola showed maximum concentration of Dichloromethane which was almost twice as compared to the other areas. The other residential areas showed more or less similar amounts of this contaminant.

Chloroform was present in all samples and most of the soil samples contained this compound at fairly similar levels. The average chloroform level in the soil sample was found to be 6.55 mg/L. The highest concentration of chloroform found at Atal Ayub Nagar was 6.77 mg/L, while the minimum found at Kanchi Chola was around 6.27 mg/L. Table 25 indicates the Halo-organics in soil samples from the UCIL factory premises.

Table 25: Dichloromethane and Chloroform in soil samples (mg/Kg) around residential areas adjoining UCIL factory premises.

Location	Dichloromethane	Chloroform
J.P.Nagar	0.0901	6.5129
Kanchi Chola	0.1700	6.2668
Nawab Colony	0.0909	6.5327
Sevin Cycle Shed	0.1790	6.6593
Atal Ayub Nagar	0.0815	6.7204
Anu Nagar	0.0995	6.6237
New Arif Nagar	0.0877	6.6174

Soil samples within the factory premises showed both dichloromethane and chloroform. The chloroform in the samples in the factory exceeded those of dichloromethane. The chloroform and dichloromethane levels were almost similar at all soil sampling sites in the factory. The average level of chloroform in the soil was 6.40 mg/Kg, which was 50 times more than dichloromethane.

Table 26: Dichloromethane and Chloroform in soil samples (mg/Kg) collected from UCIL factory premises.

Location	Dichloromethane	Chloroform
Sevin Cycle Shed	0.1790	6.6593
Sevin Plant-1	0.0809	6.6299
Sevin Plant-2	0.1595	6.4971
Alpha Naphthol	0.1177	6.6826
Pan filter area	0.1023	5.5204

All the three vegetable samples analysed showed the presence of both Dichloromethane and Chloroform. In palak, the dichloromethane levels were almost 30 times more than those present in either radish or brinjal. The average levels in the vegetable samples were 0.0284 mg/Kg.

Chloroform content was more in radish and brinjal when compared to palak. The average chloroform content in the vegetables was 7.51 mg/Kg, which was 264 times more than the mean levels of dichloromethane. Table 27 indicates the Halo-organics in vegetable samples from the UCIL factory premises.

Table 27: Dichloromethane and Chloroform in vegetable samples (mg/Kg) around residential areas adjoining UCIL factory premises.

Sample	Dichloromethane	Chloroform
Spinach	0.0797	6.1843
Radish	0.0027	8.2929
Brinjal	0.0027	8.0403

All the eight ground water samples contained both dichloromethane and chloroform. However, the dichloromethane levels in water were almost 2 times more than chloroform. Water samples from Rajgarh colony had the highest level of dichloromethane. The average concentration of dichloromethane was 1.63 mg/L. The water samples from Atal Ayub Nagar showed maximum concentration of chloroform. The average concentration of chloroform in water was 0.85 mg/L.
Table 28 indicates the Halo-organics in water samples from the UCIL factory premises.

Table 28: Dichloromethane and Chloroform in water samples (mg/L) around residential areas adjoining UCIL factory premises.

Location	Dichloromethane	Chloroform
Anu Nagar	0.2580	0.9901
Atal Ayub Nagar	0.1065	1.3591
J.P. Nagar	0.1235	0.8013
Kanchi Chola	1.7250	0.3792
Nawab Colony	0.3377	0.8544
New Arif Nagar	4.2690	0.8673
Rajgarh Colony	4.6035	0.8650
Shakti Nagar	1.6660	0.6710

All the breast milk samples contained dichloromethane and chloroform. The amounts of chloroform were 3.2 times more than those of dichloromethane levels. The breast milk samples from J.P. Nagar showed highest levels of dichloromethane, while maximum concentration of chloroform in breast milk samples, were from New Arif Nagar. The average concentrations of dichloromethane and chloroform in breast milk were 0.359 and 1.154 mg/L. Table 29 indicates the Halo-organics in breast milk samples from the UCIL factory premises.

Table 29: Dichloromethane and Chloroform in breast milk samples (mg/L) around residential areas adjoining UCIL factory premises.

Location	Dichloromethane	Chloroform
Shakti Nagar	0.4109	0.9598
Kanchi Chola	0.0928	1.3965
Rajgarh Colony	1.0896	1.1541
J.P. Nagar	0.1631	1.1337
New Arif Nagar	0.0864	1.4005
Atal Ayub Nagar	0.3080	0.8785

The soil from the Solar Evaporation Pond, a dumping site for UCIL factory, showed both dichloromethane and chloroform. The chloroform levels were almost similar to those present within the factory premises. The pond water samples adjacent to the Solar Evaporation Pond, showed dichloromethane and chloroform and their average concentration were 0.714 mg/L and 0.917 mg/L, respectively.

Table 30: Dichloromethane and Chloroform in SEP dumping site samples (mg/Kg) around residential areas adjoining UCIL factory premises.

Location	Dichloromethane	Chloroform
Solar Evaporation Pond - Soil	0.0972	6.6141
Solar Evaporation Pond - Water	0.7140	0.9165

Table 31: Summary of the analysis of chemical contamination (ppm) around UCIL Factory and adjoining residential areas in Bhopal.

	Heavy Metals				VOC	Halo-organics		Pesticides-
Samples	**Chromium**	**Nickel**	**Mercury**	**Lead**	**Chlorobenzenes**	**Dichloromethane**	**Chloroform**	**HCH isomer**
Soil - Residential Areas	0.647 (0.021 to 1.96)	1.032 (0.007- 4.77)	0.568 (0.980 - 2.43)	0.137 0.277 - 0.467)	0.932 (0.1715 – 4.1252)	0.103 (0.0815 - 0.1700)	6.546 (6.2688 to 6.7204)	1.605 (0.095 –5.0383)
Soil- Factory	0.233	2.90	1.857	0.277	0.425	0.128 (0.0809 –0.179)	6.4 (5.5204 – 6.6826)	2.041
Ground water- Residential	0.012 (0.0057 to 0.021)	1.099 (0.7155 - 1.875)	0.057 (0.0264 to 0.2758)	0.026 (0.0013 to 0.0548)	0.006 (0.0015 – 0.0149)	1.636 (0.1065 to 4.6035)	0.849 (0.3792 to 1.3591)	0.011 (0.0009 – 0.0402)
Vegetables	0.475 (0 to 1.137)	0.596 (0.9721 to 1.284)	0.837 (0 to 2.510)	0.191 (0 to 0.5733)	0.132	0.028 (0.0027 to 0.0890)	7.506 (6.1114 to 8.2929)	0.021
Breast milk	ND	0.097 (0.0581 to 0.5235)	0.129 (0.0550 to 0.6665)	0.149 (0.0380 to 0.3135)	2.854 (0.5883 – 9.5166)	0.359 (0.0772 to 1.0896)	1.594 (0.8755 to 1.4005)	2.392 (0.179 – 11.471)

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Annexure

Some Available Standards

Heavy metals	Drinking Water (mg/L) (UAEPA)	Ground Water (µg/L) (USEPA)	Soil (maximum acceptable level) mg/Kg (EU Std)	Vegetables (maximum residue limit)	Breast milk (USFDA) mg/Kg
Chromium	0.1	0.05	100		
Nickel	0.1	0.02	50		
Mercury	0.002	0.001	1	1.0 ppm (USFDA)	
Lead	0.015	0.01	100	5.0 ppm (USFDA)	

Pesticides					
Beta HCH				0.02 mg/Kg EEC legislation	0.1
Gamma HCH	0.004	0.2	0.1 mg/Kg USSR	0.5 to 3 mg/Kg (FAO, WHO)	1.0

VOC's					
Dichlorebenzene	0.6	5			2.5
Trichlorobenzene (1,3,5)					
Trichlorobenzene (1,2,4)	0.07				
Trichlorobenzene (1,2,3)					
tetrachlorobenzene					

Halo-Organics	µg/L (USEPA)				
Chloroform	80				
Dichloromethane	5	5			