The Bhopal Disaster of 1984

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The 20th anniversary of the Bhopal calamity fell on December 3, 2004. The world's worst industrial disaster in Bhopal, India, happened because of inadequate maintenance by Union Carbide and poor monitoring by the Indian authorities. Malfunctioning safety measures, inappropriate location of the plant, and lack of information about the identity and toxicity of the gas worsened the effects of the accident on people and livestock. The Bhopal disaster has raised questions about the implications of the transfer of potentially hazardous technology to the developing countries. Even after 20 years, Bhopal has not recovered. In this article, we present what happened and why and what lessons can be learned at this terrible cost.

Keywords: hazards; green revolution; methyl isocyanate; multinationals; pesticides; poisonous gas; safety failures; Union Carbide

India became independent on August 15, 1947, and its first major problem was to deal with food shortage. The problem persisted by varying degrees until the *Green Revolution*, a popular term referring mainly to the tremendous increases in cereal grain production in certain underdeveloped areas especially India, Pakistan, and the Philippines in the late 1960s through the cultivation of hybrid strains and economic changes brought by new agricultural rural practices in those countries. For a number of years now, India has been a food surplus country. The change from traditional farming to capitalist farming under the Green Revolution required pesticides among other things.

Bhopal, capital of Madhya Pradesh (MP) in central India, is a beautiful historic city. MP is a poor province by Indian standards. Until very recently the Indian National Congress Party (Congress) was in power in MP, and Mr. Arjun Singh, currently the federal Minister for Human Resources and Development, was the Chief Minister of MP in 1984. Singh played a key role in having the agricultural office of Union Carbide India Limited (UCIL) move from Bombay to Bhopal in 1968. It was supposed to help in the development of MP. In 1969, the Bhopal plant was built as the formulation plant: The Sevin Technical Concentrate was imported from the United States, and the work of blending and grinding was done in Bhopal. The manufacture of the pesticide Sevin using methyl isocyanate (MIC) was started in 1980.

Within 4 years of operation, on December 2, 1984, 30 metric tons of highly poisonous MIC gas spewed from the UCIL plant. It is estimated that almost 20,000 people died, and nearly 200,000 people were exposed to the poisonous gas by varying degrees. The plant closed after the accident, and Union Carbide became a subsidy of Dow Chemical in 1999.

Given the magnitude of the tragedy, it is not surprising that the Bhopal disaster has continued to draw the attention of media, scholars, and activists throughout the world. It has been the subject of several books (Cassels, 1993; Everest, 1985; Fortun, 2001; Jasanoff, 1994; Kuizman, 1987; Lapierre & Moro, 2001; Sufrin, 1985; Wilkins, 1987) and studies (Dhara & Dhara, 2002; Mehta, Mehta, Mehta, & Makhijani, 1990; Sriramachari, 2004; D. R. Varma, 1986; D. R. Varma & Guest, 1993). In 2002, a play "Bhopal" was staged in Canada as well as in India. The *Nature of Things* of the Canadian Broadcasting Corporation screened the documentary "Bhopal: The Search for Justice," directed by Peter Raymont and Lindalee Tracey, on the occasion of the 20th anniversary of the Bhopal disaster. The Bhopal issue has been taken up by numerous organizations. Sambhavana Foundation, which came into being as a response to the disaster, operates a free clinic for the victims, does epidemiological and envi-

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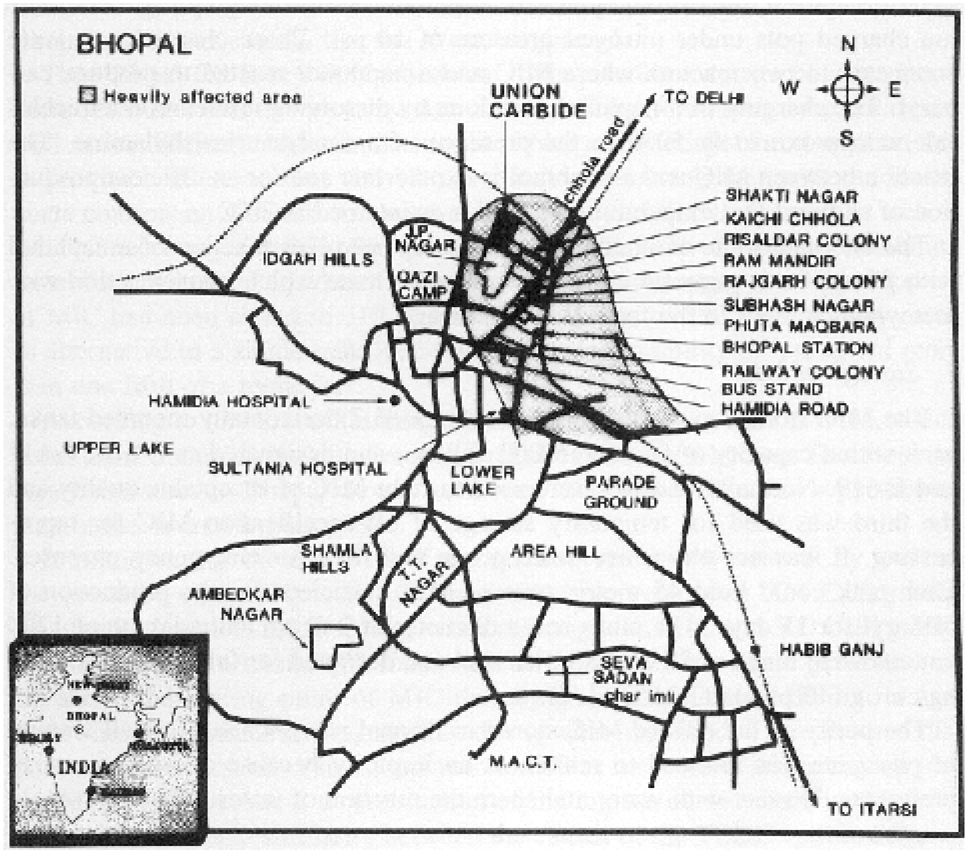

Figure 1.
Map of Bhopal showing the location of the UCIL plant and the areas most severely affected (shaded). Inset: Location of Bhopal in India.

ronmental research, and is building a hospital. Rashida Bee and Champa Devi Shukla, two survivors of the tragedy and activists of the International Campaign for Justice in Bhopal, won the prestigious Goldman Environmental Prize in 2004.

In this article, we present what happened in Bhopal and why. We outline the double standard of Union Carbide toward safety measures, the corrupt practices of India to hush the matter of hazardous operations, and structural inability of India to handle hazardous technology. In the long shadow of the 20th anniversary of the Bhopal disaster, the article outlines lessons that need to be learned.

The Shock and Awe

It was just past midnight on December 2, 1984. Nearly 30 of the 42 metric tons of MIC stored in Tank 610 of the UCIL pesticide plant escaped with considerable velocity within a matter of 45 minutes to 60 minutes. The dense cloud of the heavier-than-air gas soon settled on the shantytowns adjoining the plant showing no mercy to people, animals, and plants.[1] The exact human death toll is still to be unknown; however, it is estimated that nearly 5,000 people died within 2 days, and the death toll eventually reached upward of 20,000. A total of 200,000 in a city of 800,000 (1984 population) were exposed to the gas. More than 60,000 of them required long-term treatment (D. R. Varma, 1986). The location of the UCIL plant and areas most affected is shown in Figure 1.

India and the world were shocked in the morning of December 3. "This may be how the world will end not with a bang (with obvious reference to Nagasaki and Hiroshima) but with an ecological whimper," wrote Abu Abraham in Bombay's *Sunday Observer* of December 23, 1984 (p. 1). "City of Death" was the front cover of the December 31, 1984, issue of the fortnightly *India Today.* "India's Disaster—The Night of Death" was displayed on the front cover of the December 14, 1984, issue of *Time* magazine. The prestigious journal *Nature* noticed that

> the anguish vividly carried round the world by the television cameras seems not to have matured into the anger, even hysteria, there would have been had the accident occurred on the edge of a European city or in Connecticut (the headquarters of Union Carbide). ("Helping Out in Bhopal," 1984, p. 579)

The fear was so great among the people of Bhopal that nearly one half the population left the city during Operation Faith (December 16 to December 22, 1984) when the remaining MIC in the plant was disposed by making more of the pesticide Sevin.[2]

The general sentiment was that it was an unfortunate accident, the probability of whose occurrence should be minimized ("Bhopal's Message," 1984; Diamond, 1985; Tcheknavorian-Asenbauer, 1984). Yet many felt that the Bhopal tragedy, terrible as it was, was the price to be paid for development, for the Green Revolution. For instance, *The Wall Street Journal* declared that "of those people killed, half would not have been alive today if it weren't for that plant and the modern health standards made possible by wide use of pesticides" ("The Bhopal Tragedy," 1984, p. 26). Similarly, *The New Republic* echoed that pesticides manufactured by the Union Carbide plant in India saved 10% of the annual crop that is enough to feed 70 to 80 million people (TRB, 1985, p. 42).

Union Carbide of India Limited (UCIL)

At the time of accident, UCIL was a 50.9% subsidiary of the Union Carbide Corporation (UCC) of the United States. In the *Fortune 500* survey of the 500 largest U.S. industrial corporations, the UCC was ranked as the third largest chemical manufacturing company after Du Pont and Dow Chemical. The *Economic Times* (India) ranked the UCIL 21 in India. The UCIL plant in Bhopal was a packaged transfer with no Indian organization associated with any component of technology except for labor and some construction material. The entire package was put together by the UCC who arranged for process licenses, undertook engineering, construction, and start-up of the project (R. Varma, 1986).

Chemistry of Cyanates, Cyanide, and Isocyanates

Superficially, the terms *isocyanates*, *cyanides*, and *cyanates* appear to be related. However, there is a marked difference in the structure and toxicity of these three groups of chemicals. The unfamiliarity with these terms, and the popular belief that cyanide is the most toxic of all chemicals known, created a great deal of confusion in Bhopal.

Cyanates

The general structure of cyanates is –CNO. Thus sodium cyanate is NaCNO, and methyl cyanate is CH_3CNO. Cyanates are the least toxic of the three groups of molecules and cannot be converted into cyanides in the body (Birch & Schultz, 1946). They have been used for the treatment of sickle cell anemia.

Cyanides

The general structure of cyanides is –C=N. Potassium cyanide is KCN, sodium cyanide is NaCN, and hydrogen cyanide is HCN. HCN is the most toxic of all cyanides by inhalation. KCN is less toxic than HCN but much more toxic than NaCN. The faster is the dissociation of the toxic moiety CN from the specific cyanide the greater is its toxicity. Because in sufficient doses (by injection or oral ingestion) KCN can cause painless death in a very short time, it has been used for execution and suicide. Cyanide (–CN) has a very high affinity for cellular cytochrome oxidase, and inactivation of this enzyme shuts off oxygen utilization by cells; death results from absolute asphyxiation. Nonfatal quantities of –CN can be detected in the blood of most people, specially among smokers. An enzyme that can inactivate cyanide ion is present in humans and animals; consequently, if a person does not die from cyanide poisoning within a few hours, survival is almost a rule. Cyanide poisoning is not known to result in long-term toxic effects. Studies with MIC indicate that on a concentration basis it is much more toxic than HCN, although death from MIC intoxication takes much longer (hours and days) than after cyanide poisoning (usually in minutes). Maximum allowable concentration of HCN is 10 parts per million (ppm), at which concentration MIC is intolerable and will cause death in a proportion of affected individuals (D. R. Varma, 1989).

Isocyanates

Isocyanates are highly reactive members of the heterocumelene family. Their general chemical structure is R-N=C=O. Methyl isocyanate (CH_3-N=C=O) is a monoisocyanate (in this case, R is CH_3). The existence of adjacent double bonds confers high reactivity to isocyanates by a cumulative action. That is why MIC is very toxic. All isocyanates are toxic, and their toxicity is greater following inhalation than following oral ingestion (D. R. Varma, 1986).

MIC is the most toxic member of the isocyanate family. At room temperature, MIC is a colorless liquid. MIC is flammable; its molecular mass is 57.05, specific gravity 0.96 relative to water at 20°C, vapor pressure 348 mm Hg (464 mbar) at 20°C and vapor density 1.97 relative to air. The boiling point of MIC is 39.1°C, which implies that some MIC will vaporize at a room temperature of 23°C and all of it can exist as vapor in Bhopal on certain hot days of the summer. Because MIC is odorless, contact with it is noted only because of toxicity (watering of eyes, throat irritation). The Occupational Safety and Health Administration in the United States has set exposure limits to MIC as 0.02 ppm (or 0.05 mg/m^3) during an 8-hour period (D. R. Varma, 1986).

Synthesis of Carbamate Pesticides

MIC was used as an intermediate in the manufacture of a variety of carbamate pesticides as follows:

1. Petroleum coke (2C) was reacted with oxygen to produce 2CO.
2. CO and chlorine were reacted to produce phosgene ($COCl_2$).
3. Phosgene and methylamine (CH_3NH_2) were reacted to produce methylcarbamoyl chloride ($CH_3NHCOCl$) plus HCl.
4. Methylcarbamoyl chloride was then pyrolyzed to yield MIC (CH_3NCO) and HCl.
5. In the last step, MIC was reacted with a slight excess of α-naphthol in the presence of a catalyst in carbon tetrachloride solvent to produce cabaryl.

The Leak

Reaction of MIC with water generates heat far above its boiling point. During the cleaning operation in the night of December 2, 1984, a small quantity of water went through the pipe into the MIC Tank 610. The heat generated by the reaction between water and MIC transformed liquid MIC into gas. The pressure became sufficiently high, rupturing the disc, and MIC spewed through the vent into the atmosphere (Diamond, 1985). There is little substance to the UCIL claim that the accident was a result of sabotage by some disgruntled workers.

Faulty Location

The UCIL plant was built on the outskirts of the city barely one km from the railway station and 3 km from two major hospitals, Hamidia and Sultania (Figure 1). This was done against the advice of authorities. For example, the Bhopal Development Plan of August 25, 1975, had already suggested that "obnoxious industries" including manufacturing pesticides and insecticides be located to an industrial zone 25 km away. M. N. Buch, then commissioner and director of town and country planning for the state, ordered the Union Carbide plant to locate manufacturing of carbamates away from the city because the risks of a pesticide formulation plant are very different from a plant that manufactures the basic material for pesticides. According to him, with such a plant, people should not live within many miles of the plants (Reinhold, 1985; R. Varma, 1986).

Careless Handling of MIC

MIC was stored in three tanks, each with a capacity of 15,000 gallons. All three tanks were in use. It is expected that one tank will be kept free for emergency purposes. In the United States, Japan, and Germany, MIC was either used up as it was produced or stored only for brief periods and never in such huge quantities as in Bhopal. Tank 610 had 6.4 tons of MIC prior to October 7 to which was added MIC produced from October 7 til October 22. Thus MIC was not only kept for 55 days, but Tank 610 contained two separate pools of MIC. It is expected that tanks should be no more than half full; however, prior to the fateful night in Bhopal, the Tank 610 was 87% full, which is far above the recommended capacity of 50% at the West Virginia plant and the 60% specification for the Bhopal plant (Diamond, 1985; Reinhold, 1985; Varadarajan, 1985).

Tanks containing MIC are required to be kept under refrigeration; this elementary caution was violated at Bhopal. The Union Carbide manual (Union Carbide, 1978) specifies that the alarm should respond whenever the temperature goes above 11°C; in Bhopal it was set at 20°C. Most evidence suggests that MIC in the Bhopal plant was generally at or above 15°C.

Failure of Safety Devices

The scrubber and flare tower, which at their best could handle minor leaks, were nonfunctional at the time of the accident. The scrubber, if functional, can neutralize MIC entering at 90 kg/hour at 35°C and a maximum pressure of 15 pounds per square inch (psi); the pressure at which MIC escaped was approximately 200 times higher at 6 to 10 times the desired temperature. Similarly, the flare tower can only burn miniscule amounts of MIC. The third main safety device, the water spraying system, was functional and turned on at 1:00 AM in the morning of December 3; however, it could shoot water only up to a height of 12 meters to 15 meters whereas MIC escaped at a height at approximately 50 meters (Lepkowski, 1985; R. Varma, 1986).

Shoddy Maintenance

There were serious lapses in the day-to-day operations. The practice of employing degree holders as operators and providing them with a 6-month training was abandoned. Some operators were high school graduates and brought from other plants. The staff was reduced from 12 operators, 3 supervisors, 2 maintenance supervisors, and 1 superintendent per shift to 6 operators, 1 supervisor, and no obligatory superintendent (R. Varma, 1986). The plant was not automated to monitor leaks, which used to be detected by workers by irritation of eyes and throat. No effective public warnings system was installed. The alarm was similar to those sounding for various other purposes.

Callousness Toward Warnings

Many of the problems, which ultimately led to the disaster, were identified as early as May 1982 by a team of American experts (L. K. Kail, J. M. Poulon, C. S. Tyson) sent by the UCC. The team found instances of leaky valves, cleaning of filters without inserting a slip blind, malfunctioning pressure gauges, malfunctioning spray water system and so on (Union Carbide, 1982). It is doubtful that these recommendations were implemented.

Another noteworthy warning came from a local journalist Raj Kumar Keswani. In a Hindi weekly, *Saptahik* of September 17, October 1, and October 8, 1982, Keswani warned policy makers and public with prophetic headlines: “Save, Please Save This City,” “Bhopal on the Mouth of a Volcano,” and “If You Don’t Understand, You Will be Wiped Out.” He again wrote a long article along the same lines in a Hindi daily newspaper *Jansatta* on June 16, 1984, and to the Chief Minister about the danger. His warnings were largely derived from the problems cited by Union Carbide’s safety report of May 1982.

Serious attention should have been paid to criticisms of the UCIL operations because at least four other mishaps happened in the past. For instance, the inquiry report of the phosgene accident of December 1981 in which plant operator M. Ashraf died, was submitted in March 1984. Nothing was done by the Labor Department of India until October when two senior officials finally learned about the report. They recommended improvements at the factory; however, no action was taken. Workers protested; instead of dealing with the accident, the management dismissed two protesters on flimsy charges (Ramaseshan, 1984).

According to some journalists (Ram, 1984; Vaidyanathan, 1985), such manner of functioning was possible mainly because of the relationship that existed between the UCIL and the Indian administration. The company’s guest house on Shyamla Hills was always at the disposal of the Chief Minister, state government officials, and union ministers. Relatives of several ministers and senior bureaucrats were on the company’s payroll.

The most likely reason for negligence on the part of the UCIL was the dwindling market for its pesticide, Sevin. A major drought struck India in 1977, which forced many farmers to borrow heavily from the government. When these loans started to come due in 1980, the farmers started buying pesticides produced by small operations at almost one half the price of UCIL’s Sevin. The sales of Sevin dropped by 23% in 1983. As the profit of the UCIL shrunk, the management ignored safety measures and stopped upgrading of equipments (Bhargava, 1985).

Aggravating the Tragedy

Late and misleading warning about the MIC leak increased the human cost of the disaster. The leak was detected at 11:30 PM on December 2; however, the warning signal was started 2 hours later at 1:30 AM on December 3. The actual duration of the MIC leak is estimated to be 45 minutes to 60 minutes. By the time the siren went into effect, people were already awakened by the irritation in the eyes and throat. This, however, was ignored because minor leaks were common.

Around midnight, the operator noticed unusually high pressure in Tank 610 and reported this to the production assistant (Diamond, 1985; R. Varma, 1986). A few minutes past midnight of December 3, the production assistant noticed that the rupture disc and the safety valve (next in sequence) had burst. By 1:00 AM of December 3, MIC was escaping through the nozzle of the 33-meter high vent.

The public siren was turned on around 2:00 AM of December 3, 1984. Furthermore, the instructions provided by the administration proved worse than if no instructions had been given. Because the police did not know what had leaked and what to say, they blared with loud speakers: "Run! Run! Poison Gas Is Spreading!" Consequently, people ran and inhaled more of the poison than they would have had they not run. Only if the evacuation of about 100,000 residents from the vicinity of the plant on the northeast side was done at the first sign of the MIC leak, the number of deaths that followed could have been considerably less. When MIC started spewing in huge quantities, the only useful warning was to ask people not to run but rather lie down on the ground and cover their faces with wet cloths. Indeed Union Carbide's (1978) manual clearly states that: "Methyl isocyanate is a hazardous material by all means of contact. Vapors are extremely irritating . . . may cause fatal pulmonary edema" (p. 6). It is important to note that a large majority of all deaths within the first 48 hours of the leak were due to pulmonary edema.

The Union Carbide headquarters and its West Virginia plant can be squarely blamed for aggravating the tragedy by not informing or misinforming about the nature and toxicity of the chemical that had leaked. The first misinformation was given by Dr. B. H. Avashia of the West Virginia plant who implied that hydrogen cyanide had leaked and people should be given the cyanide antidote sodium thiosulfate; a generous quantity of sodium thiosulfate was donated by the German toxicologist Dr. M. Daunderer. The confusion was so great that demand to treat victims by sodium thiosulfate remained an issue for months. As mentioned earlier, if the chemical was hydrogen cyanide, most deaths would have occurred within a few hours of the leak, and sodium thiosulfate could not have saved any lives days or months after. On the other hand, sodium thiosulfate could improve tissue oxygenation even months after by inactivating cyanide present in the body for a number of reasons, notably smoking; therefore, there was neither a need to recommend nor ban its use. Because UCIL officials grossly underemphasized the toxicity of MIC, the possibility of phosgene leak instead of MIC found currency in Bhopal (R. Varma, 1986).

In addition to suppressing information, continuous misinformation started emanating by the administration with the help of scientific experts to cover up the real effects of the gas on people. The confusion was magnified by statements made by a team of medical experts sent by Union Carbide immediately after the accident. The team comprising Dr. Hans Weill (Pulmonary Division, Tulane Medical Center, New Orleans, Louisiana), Dr. Peter Halberg (professor of clinical ophthalmology, New York Medical College), and Dr. Thomas L. Petty (School of Medicine, University of Colorado) asserted that MIC will be rapidly degraded on contact with body and will not produce any systemic or long-term effect. The conjecture of this team was reiterated by Dr. James Melius, chief of the Hazard and Technical Assistance Branch of the National Institute for Occupational Safety and Health (NIOSH) in Cincinnati, Ohio, who was invited along with three others by the government of India.

The Killer Gas

The immediate effect of the poisonous gas was irritation in the eyes and difficulty in breathing. By early morning on December 3, 1984, streets were littered with dead or dying humans, buffalos, cows, dogs and other animals. Trees were denuded. It is interesting to note, houseflies were unaffected by the gas, perhaps because they lay still at ground level. Those who could manage were rushing to the hospital. Deaths within the first 4 days of the leak were caused by pulmonary edema. The condition is identical to severe acute respiratory syndrome (SARS), which is caused by a virus and which caused several deaths in China and Canada in 2003. In short, Bhopal suffered from an epidemic of chemically induced SARS. There is no specific treatment of such a condition; supporting therapy is needed. Even in the industrialized world, treatment would have been nearly impossible had SARS affected thousands on thousands of people within a very short time.

MIC Toxicity

There was only one report on the toxicity of MIC in the literature (Kimmerle & Eben, 1964) at the time of the Bhopal disaster. This led the prestigious British journal *Lance* to comment: "In a year's time we will have learned a lot more about methyl isocyanate—at an appalling price" ("Calamity at Bhopal," 1984, p. 1379). Indeed, we did learn a lot in a few years' time.

The acute toxicity of the MIC leak included difficulty in breathing, eye irritation, corneal damage, vomiting, unconsciousness, fatigue, and death (Anderson, Muir, & Mehra, 1984; Dhara & Dhara, 2002; Varma & Guest, 1993). During the years, it became clear that victims have developed other complications such as reduced lung capacity, psychiatric problems, cardiac and immunologic problems, damage to internal organs, and so on (Dhara & Dhara, 2002; Kamat et al., 1992; Varma & Guest, 1993). More than 40% of pregnant women exposed to the gas failed to deliver live babies (D. R. Varma, 1986, 1987, 1991). A more alarming long-term toxicity was reported by Ranjan et al. (2003): These authors found that boys born to parents exposed to the gas are significantly shorter than their unexposed cohorts, suggesting possible genetic effects. Anecdotal reports suggest menstrual problems in girls affected by the gas.

Experimental data using mice and rats clearly established that exposure to MIC at as low as 9 ppm for 1 hour to 3 hours caused deaths in more than 50% of animals (Varma, Ferguson, & Alarie, 1987); it might be noted that hydrogen cyanide can rarely be fatal at less than 30 ppm. Reproductive toxicity of methyl isocyanate as well as its metabolites have been reported in rats and mice (Guest & Varma, 1991, 1992; Varma, et al., 1987).

Water Pollution

Bhopal's underground water is polluted with toxic chemicals including mercury and is considered unsafe for drinking. This pollution is caused by activities of UCIL during several years of its operation and is not entirely due to the December 3 disaster. A group of survivors led by Rashida Bee and Champa Devi Shukla, who were awarded in May 2004 the prestigious Goldman Environmental Prize, have been campaigning that Dow Chemical, the current owners of Union Carbide, undertake the cleaning of the environment.

Relief and Rehabilitation

As soon as the news of the disaster reached the world, hundreds of American lawyers descended to Bhopal trying to enlist clients for cases to be filed in American courts. It was chaotic. Fortunately the government of India deemed it to be the sole authority regarding compensation, and the Bhopal mayor signed an agreement with American lawyer J. P. Coale to file a suit in a U.S. court on behalf of the municipal corporation. The government of India paid rupees, 10,000 (U.S. $800 at 1984 rate) for each dead individual and approximately $100 for each hospitalized member of the family. The government of India announced a relief fund of $4 million on December 24. However, people were cremated or buried in mass, and there remains to this day confusion about the number and the identity of the dead.

A settlement was reached between the government of India and the Union Carbide for $470 million, 4 years after the accident on February 14, 1989. Part of this money was distributed to the victims; however, a substantial sum was retained by the Reserve Bank of India because of legal issues. On July 19, 2004, the Supreme Court of India ordered that the remaining $327.5 million (approximately 15 billion Indian rupees) be distributed to the victims. It is not clear if the victims will indeed get the money they rightfully deserve.

Conclusion

The Bhopal disaster has lessons for the developing and developed countries. The developing countries need modern technologies to meet the needs of the population and reach par with the developed countries. Developments requiring chemical and nuclear plants can never be absolutely safe. However, if these plants are to be employed, utmost care should be taken to ensure safety. Given the technical demands of such modern production plants, safety measures should be more stringent in developing than in developed countries.

The Bhopal disaster undoubtedly has been the worst so far. However, warning signals had been there for a while. Several accidental spills of dangerous chemicals had taken place before the Bhopal episode. The cyclohexane explosion in Flixborough in 1974 prompted the establishment of an Advisory Committee on Major Hazards in the United Kingdom. The European Economic Community Council Directive was triggered by the Italy's Seveso accident of 1976 in which trichlorophenol contaminated with dioxin was released in the atmosphere (Regigiani, 1983). Yet Bhopal happened, which implies the need of more effective measures (Baxter, 1986). It is not unrealistic to assume that the sociopolitical situation in developing countries would allow negligence. Therefore, it will be appropriate that international bodies such as the International Civil Aviation Organization under the World Health Organization and International Labor Organizations be established.

The corporate world is not a humanitarian organization. Each undertaking by multinational corporations (MNC) is for profit, which requires cost cutting. This cannot change. Consequently in the developing and developed world, safe operation of hazardous industries require government control, intervention, and subsidies. The driving principle of India's postindependence industrialization was massive state intervention, though criticized by many as cost-ineffective. This policy should still be followed with respect to hazardous industries. At the same time, MNCs should take into consideration certain constraints of the developing world in setting up hazardous industries. In the case of Bhopal, the damage would have been much less had the factory been far away from the main city not only as it was in the 1970s but what it was predictably going to be 10 or 20 years later. As well, rigorous inspections about safety must be done more frequently than it was done in Bhopal.

To sum up, what the developing countries need is balanced development based on maximum exploitation of their traditional skills, indigenous technology, and Western know-how that can be reliably adapted to their needs.

Notes

1. Large settlements, many illegal, had taken place adjacent to the UCIL pesticide plant by the time of the disaster. The Chief Minister Arjun Singh had invited filmmakers Tapan Bose and Suhasini Mulay to make a documentary on the transfer of the ownership of the hutments to their illegal occupants. The filming had not started, and the industrial disaster struck Bhopal. The filmmakers made a documentary, *Bhopal: Beyond Genocide*.

2. It may sound ludicrous but Dr. S. Varadarajan, the Indian government's chief scientist in the Bhopal disaster investigation and the director of the India's Council of Scientific and Industrial Research (CSIR), held a sealed vial of MIC in his hands in front of the camera at a press conference to assure the people that MIC after all can be contained.

References

Anderson, N., Muir, M. K., & Mehra, V. (1984). Bhopal eye. *Lancet*, *2*, 1481.

Baxter, P. J. (1986). Editorial: From Flixborough to Bhopal: Is legislation enough? *British Journal of Industrial Medicine*, *43*, 1-5.

Bhargava, P. (1985). The Bhopal tragedy: A middle word. *Economic and Political Weekly*, *20*(22), 962-965.

Bhopal's message [Editorial]. (1984, December 5). *Christian Science Monitor*, p. 31.

Birch, K. M., & Schultz, F. (1946). Actions of cyanate. *British Journal of Pharmacology*, *1*, 186-193.

Calamity at Bhopal [Editorial]. (1984). *Lancet*, *2*, 1378-1379.

Cassels, J. (1993). *Uncertain promise of law: Lessons from Bhopal*. Toronto, Canada: University of Toronto Press.

Dhara, V. R., & Dhara, R. (2002). The Union Carbide disaster in Bhopal: A review of health effects. *Archives of Environmental Health*, *57*, 391-404.

Diamond, S. (1985, January 28). The Bhopal disaster: How it happened. *The New York Times*, p. A1.

Everest, L. (1985). *Behind the poison cloud*. Chicago: Banner Press.

Fortun, K. (2001). *Advocacy after Bhopal: Environmentalism, disaster, new global orders*. Chicago: University of Chicago Press.

Guest, I., & Varma, D. R. (1991). Developmental toxicity of methylamines in mice. *Journal of Toxicology and Environmental Health*, *32*, 319-330.

Guest, I., & Varma, D. R. (1992). Teratogenic and macromolecular synthesis inhibitory effects of trimethylamine on mouse embryos in culture. *Journal of Toxicology and Environmental Health*, *36*, 27-41.

Helping out in Bhopal [Opinion]. (1984). *Nature* (London), *312*, 579-580.

Jasanoff, S. (Ed.). (1994). *Learning from disaster: Risk management after Bhopal*. Philadelphia: University of Pennsylvania Press.

Kamat, S. R., Patel, M. H., Pradhan, P. V., Taskar, S. P., Vaidya, P. R., Kolhatkar, V. P., et al. (1992). Sequential respiratory, psychologic, and immunologic studies in relation to methyl isocyanate exposure over two years with model development. *Environmental Health Perspectives*, *97*, 241-253.

Kimmerle, G., & Eben, A. (1964). Zur toxicitat von methylisocyanat und dessen quantitativer bestimmung in der luft [Toxicity of methyl isocyanate and quantification in the air.]. *Archiv fur Toxikologie*, *20*, 235-241.

Kuizman, D. (1987). *Inside the Bhopal catastrophe*. New York: McGraw-Hill.

Lapierre, D., & Moro, J. (2001). *It was five past midnight in Bhopal*. Delhi, India: Full Circle Publishing.

Lepkowski, W. (1985). Bhopal. *Chemical and Engineering News*, *63*, 16-26.

Mehta, P. S., Mehta, A. S., Mehta, S. J., & Makhijani, A. B. (1990). Bhopal tragedy's health effects: A review of methyl isocyanate toxicity. *Journal of American Medical Association*, *264*, 2761-2787.

Ram, M. (1984, December 20). Counting the cost. *Far Eastern Economic Review*, pp. 10–11.

Ramaseshan, R. (1984). Profit against safety. *Economic and Political Weekly*, *19*(51), 2147-2150.

Ranjan, N., Sarangi, S., Padmanabhan, V. T., Holleran, S., Ramakrishnan, R., & Varma, D. R. (2003). Methyl isocyanate exposure and growth patterns of adolescents in Bhopal. *Journal of American Medical Association*, *290*, 1856-1857.

Regigiani, G. (1983). Anatomy of TCDD spill: The Seveso incident. In *Hazard assessment of chemicals* (pp. 269-341). New York: Academic Press.

Reinhold, R. (1985, January 31). Disaster in Bhopal: Where does blame lie? *The New York Times*, p. A8.

Sriramachari, S. (2004). The Bhopal gas tragedy: An environmental disaster. *Current Science*, *86*, 905-920.

Sufrin, S. C. (1985). *Bhopal: Its setting, responsibility and challenge*. New Delhi, India: Ajanta.

Tcheknavorian-Asenbauer, A. (1984, November/December). Bhopal: Lessons for all of us. *United Nations Disaster and Relief Organization News*, pp. 5-6.

The Bhopal tragedy [Editorial]. (1984, December 10). *The Wall Street Journal*, p. 26.

TRB. (1985, January 7-14). Bhopal in your court: Why American justice is bad for India. *The New Republic*, p. 42.

Union Carbide. (1978). *Operating manual: Methylisocyanate unit*. Danbury, CT.

Union Carbide. (1982). *Operational safety survey: Co/MIC/Sevin units*. Danbury, CT.

Vaidyanathan, A. (1985, February 21). A sorry technological tale from India. *New Scientist*, p. 21.

Varadarajan, S. (1985). *A scientific enquiry into the methyl isocyanate leak in Bhopal*. New Delhi, India: Council of Scientific and Industrial Research.

Varma, D. R. (1986). Anatomy of the methyl isocyanate leak in Bhopal. In J. Saxena (Ed.), *Hazard assessment of chemicals* (pp. 233-289). Washington, DC: Hemisphere.

Varma, D. R. (1987). Epidemiological and experimental studies on the effects of methyl isocyanate on the course of pregnancy. *Environmental Health Perspectives*, *72*, 153-157.

Varma, D. R. (1989). Hydrogen cyanide and Bhopal. *Lancet*, *2*, 557-558.

Varma, D. R. (1991). Pregnancy complications in Bhopal women exposed to methyl isocyanate vapor. *Journal of Environmental Science and Health*, *A26*, 1437-1447.

Varma, D. R., Ferguson, J. S., & Alarie, Y. (1987). Reproductive toxicity of methyl isocyanate in mice. *Journal of Toxicology and Environmental Health*, *21*, 265-275.

Varma, D. R., & Guest, I. (1993). The Bhopal accident and methyl isocyanate toxicity. *Journal of Toxicology and Environmental Health*, *40*, 513-529.

Varma, D. R., Guest, I., Smith, S., & Mulay, S. (1990). Dissociation between maternal and fetal toxicity of methyl isocyanate in mice and rats. *Journal of Toxicology and Environmental Health*, *30*, 1-14.

Varma, R. (1986). *The Bhopal disaster: Implications for policy making on hazardous technology in the third world*. Unpublished master's thesis, Rensselaer Polytechnic Institute, New York.

Wilkins, L. (1987). *Shared vulnerability: The media and American perceptions of the Bhopal disaster*. New York: Greenwood.

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