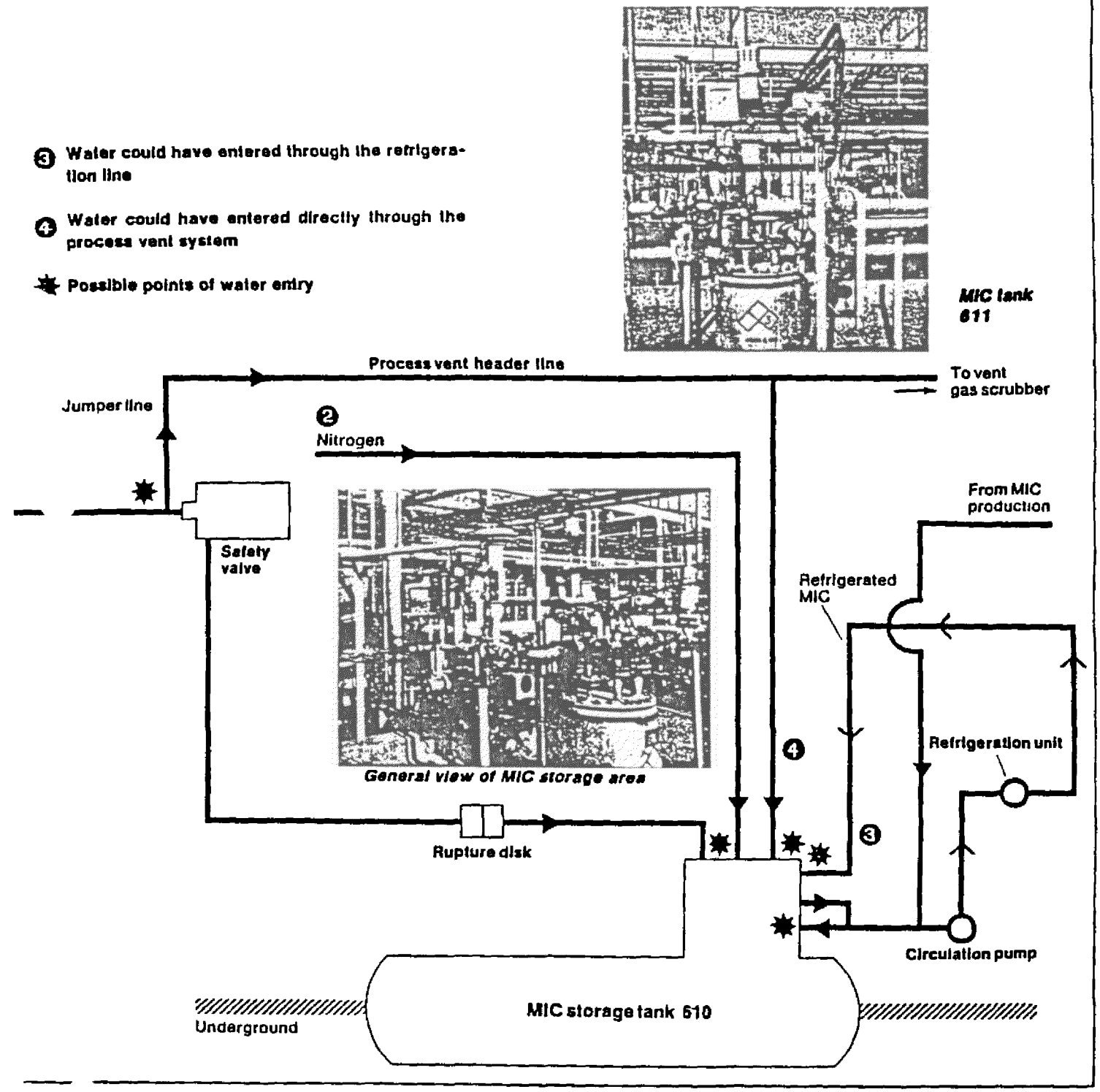


shops and human beings moving nonstop from dawn to hours past dusk. In one stricken area, signs of physical change stand out: a few television antennas on rooftops, new homes sturdier than the shacks they replaced, drainage canals in place, new paving on the pathways.

The city is no longer as stunned as it was a few months ago, though thousands are debilitated and

unable to work. Mental illness as a result of the accident is one of the most serious health problems. The official government death toll is around 1800. Doctors are willing to concede that another 500 to 1000 could have died unaccounted for during the first 24 hours. Official state government figures say 320,000 persons out of Bhopal's total population of about 1 million were affected in some way, about 14,000 "seriously." About $2.3 million has been spent on cash payments to families who lost members in the tragedy.

It is difficult, however, to measure what level of help the city needs. Officials tick off assistance figures—cash payments to families with fatalities, numbers treated for lung fibrosis, estimates of stillbirths, pounds of rice and wheat distributed, rupees handed out, the 20,000 x-rays and 35,000 clinical tests performed at Hamidia Hospital, the 1775 beds available now to gas victims.

But the numbers mean little against the magnitude of the disaster, still incomprehensible today. In any of the 30 urban wards, chats with people that were affected by the gas always reveal some unmet need. "These days, everyone is a gas victim," quips one government official. As Bhopal's current mayor Deepchand Yavad indicates, one may as well assume everyone in Bhopal was gassed. But that's a politician talking. Bhopal's pistonlike vitality makes one question claims of any urban malaise there.

Medical care, especially for lung, eye, and intestinal damage, is readily available. Every day hundreds line up at volunteer clinics, mobile treatment centers, or government outpatient facilities around the city. But an issue of high controversy is the extent to which affected persons are being actively sought. Local medical officials say that 34,000 persons have been visited by doctors inquiring about any problems. Records are being kept on everyone being treated. But to critics that isn't enough. Too many victims, they believe, are being ignored.

So there are stories in Bhopal today, and stories within stories—about the cause of the disaster, the dazzling pastiche of short- and long-term health effects, the relief measures, the controversy over the presence of cyanide in victims' bodies, the behavior of Carbide during the early hours of the disaster, the tangled legal story, the state of morality and legality in a culture as contradictory as India's.

The cause: its engineering, its implications

After a year, little is known for certain about what caused the runaway reaction in tank 610 at the Bhopal plant. What is well known, of course, is that the MIC stored in it underwent a hydrolysis reaction that, in turn, triggered a series of heat-generating polymerizations, additions, and degradations.

The resulting pressure burst the tank's rupture disk, blasted through the pressure valve just above it, and the gases surged about 600 feet along the 8-inch relief vent line, past various branch lines, and into the scrubber. They overwhelmed the scrubber's capacity (it was designed only to handle process vent gases, not runaway reactions from storage) and the gases escaped unneutralized.

The flare tower, also designed only for process vent products and moderate flows from the storage area, was shut down for repair. Since the plant was not producing MIC or anything else that night, it made little sense to operating personnel to keep the flare burning. Moreover, a system of pressurized sprinklers that would have formed a "water curtain" over the escaping gases was itself deficient. Water pressure turned out to be too low to reach the height of the escaping gas.

Essentially three theories prevail to explain how it happened. One is sabotage (or mischief) by the insertion of water or contaminants into one of the lines leading into the tank. Carbide says its studies indicate that up to 240 gal of water could have entered this way. No other explanation but one of deliberate intent makes sense, the company says. The vast majority of Indians scorn the sabotage theory.

A second theory involves the "missing slip blind," whereby a worker, ordered to wash out a series of 2-inch pressure-safety valve lines near the MIC production unit, forgot to insert a disk meant to prevent water from rising up into the main vent line, called the relief vent header. The water, the theory goes, flowed up the line toward the MIC storage area, passed into a jumper line connected to a process vent line that led directly into the tank. This is the theory that labor, environmental, and popular activists embrace because its source is workers who claim to know what happened.

The third theory is inadvertent contamination by combinations of rust, metallic ions, chloride ion, as little as a "cupful" of water, because of lax monitoring, sloppy maintenance, and inferior technology. Indian scientists doing their investigation tend toward this view and, believing it, are warning the U.S. that until Carbide itself fully understands what happened, it could happen again wherever MIC is stored.

As the UCIL production superintendent, S. P Choudhary, told C&EN during a tour of the Bhopal plant last month, "We just didn't know that MIC could be that reactive." Choudhary, one of the UCIL management group facing criminal prosecution by the Madhya Pradesh government, rules out all theories that would account for process contamination of lines leading to tank 610. "We do not believe that a small amount of water would have caused this runaway chemical reaction," UCIL says in a statement.

Jackson B. Browning, the parent company's vice president for health, safety, and environmental affairs, adds that the small amount of heat generated by such a small input of water would have been absorbed by the bulk of the contents.

of Carbide, gas, and death. Strange sores, susceptibility to tuberculosis, persistently lowered oxygen transport are some of the complications rendered by exposure to the gases.

Some patients are classic cases, such as Dropdi Bai, a 55-year-old woman who has been hospitalized with pulmonary problems ever since the first night. Bai is special, because she is one of the few gas victims of Bhopal who has been under surveillance ever since the leak. She is likely to remain in the MIC ward of Hamidia Hospital for a long time. K. S. Gaur, the physician who administers the ward, says her major pathology is bronchiotitis obliterans—blockage of her lungs air passages. She is being given cortisone to reduce inflammations. She arrived at the hospital in a coma and showed signs of cyanosis. Sodium thiosulfate, the standard antidote to cyanide exposure, was tried twice on her, Gaur says, but with no relief.

Most of the research and treatment in the ward, he says, involves the effect of MIC on the lungs and on lung function. Other studies include the psychiatric aspects, gastrointestinal complications (varied and common), and the long-term complications of drugs such as cortisone, sodium thiosulfate, and Levamisol. "Many symptoms," he says, "can be explained by immunological disturbances."

The Indian agency in charge of continuing biomedical research on the Bhopal tragedy is the Indian Council on Medical Research, headed by V. Ramalingaswami. Located in New Delhi, ICMR has spent $2 million in research so far involving about 150 researchers. And gradually Ramalingaswami hopes most of the followup research and continuous monitoring will be done in Bhopal itself.

The most serious overt problems researchers are investigating involve the lungs, he says. "Whereas eye effects appear to be abating, lung problems are persisting. We're looking at the nature of the disturbances induced by MIC. For those who received moderate to high exposure of the gas, lung edema developed rapidly, and scarring of the alveoli is common. These changes also have made the patients susceptible to pneumonia.

"Extensive studies have shown," Ramalingaswami adds, "that patients have an obstructed as well as restrictive element." That is, they not only absorb less oxygen but breathe in less as well. The restrictive aspect could be due to muscle spasms that constrict and narrow the lumen.

"Lung damage is the most serious and most important of our efforts," he says. Bronchodilator drugs are the most common treatment, but if the causes of the lung problems are getting increasingly subtle, other forms of therapy may be needed, he says. Breathing therapy, for example, is just being started. And it turns out that instruction in yoga breathing techniques is the form of physiotherapy chosen. Researchers are saying there is no known technique more effective for expanding lung capacity.

Results of research on Bhopal victims by India's industrial toxicology center

Total studied:
508 males, 601 females
Age groups:
50%—10 to 35 years
17%—36 to 45 years
16%—under 15 years
9%—46 to 55 years
8%—over 56 years
Average monthly income:
300 rupees ($25)
Distance from factory:
61% less than 2 km
31% 2 to 4 km
Chest x-rays performed:
903, of which 739 were normal, 164 abnormal
91 suggested definite pathology
48 showed changes attributed to MIC
Biochemical studies:
Glutathione level reduced in 30%, indicating hampering of detoxification mechanism and impairment of redox potential of biological system
Immunological studies:
55% showed lower phagocytic ability
Chromosomal studies:
31% showed chromosomal aberrations
Lung function tests:
39% showed ventilatory impairment
Behavioral/psychological studies:
Difficulty in concentration was most common complaint. Also confusion, poor memory, headache, irritability, depression

The immunological aspect also could be involved in explaining some of the more subtle, restrictive aspects of the lung damage, he adds. One study involving Indian scientists and Meryl Karol, an immunotoxicologist from the University of Pittsburgh, turned up detection of circulating antibodies after animal exposure to MIC—now called the MIC-specific IGE antibody. "If one detects it in the patients, the finding could lead us to believe the obstructive element could be the consequence of this immunological change."

About 3000 pregnant women were exposed to the gases, according to Ramalingaswami, and miscarriages and stillbirths were frequent. In the first 20 weeks, 436 spontaneous abortions occurred out of 2600 pregnancies. The normal rate in Bhopal is 6 to 10%. "Malformations are still being studied, although doctors are not noticing any increase of obvious birth defects," he says. "The genetic and cancer aspects of the gasing are the biggest unkowns and will have to be followed for years."

Heart surgeon R. K. Bisarya, the Bhopal mayor at the time of the tragedy and now back in full-time medical practice, takes a dour view of the medical situation in the city.

"Long-term effects are showing up now," he says. "And they are much worse than I expected. I am happy about the condition of eyes, however. I thought we'd have thousands of people needing corneal transplants. I'm glad to see that few do. But the long-range effects are bad. People's vitality is continuing to decline. Many feel they are not going to survive. There is lots of colitis, diarrhea, ulcers. A lot of female

One particular sabotage theory, advanced by Carbide during Congressional hearings after the disaster, also has been ruled out by Choudhary. According to that scheme, the "saboteur" was supposed to have attached a water hose at the source of the nitrogen line that led to the tank and simply let the water run. That scenario has several holes. For one, the source of nitrogen was at least half a mile away from the tank, in an area owned by the company that supplied nitrogen to the Carbide plant. The pressure needed to reach the MIC tank, which itself was under positive pressure, however slight, would have been too great. More telling, though, is that investigations showed no trace of water in the nitrogen line after the accident.

The slip blind theory is also illogical, he says. The reason is that a valve a few inches up from where the slip blind was to have been placed was, records show, closed. Even if the valve leaked, he says, it is improbable that even small amounts of water would have risen about 12 feet to a line that widened to a diameter of 8 inches and then continued some 600 feet to a storage tank that not only was under pressure but, by that route, closed to entry of anything (both the pressure valve and rupture disk were closed tight).

But there was another way not mentioned by Choudhary, via that jumper line between the relief valve line and process vent line. This line, open or s[illegible] by valves—how many isn't clear—led directly to t[illegible]ank. Everyone who has studied the accident agrees this could be a port of contaminant entry. Contaminants might have passed along the relief valve line, across the jumper line, into the process vent line, and into the tank. The scenario assumes a lot of valves that were not just leaky but open. A third option was the nitrogen line at the area of entry into the tank. A fourth involves lines that carried MIC out to a refrigeration unit and back into the tank.

So Choudhary says there is only one option left: "Someone deliberately did it. There are lots of places in any plant where with a simple tool you can detach a linkage and add a contaminant." And a source of water existed a few feet away from the tank. But one needs a motive. Carbide hasn't really supplied the motive, except for newspaper accounts of a radical Sikh group that claimed credit for the disaster. The problem is that the existence of such a group is yet to be verified nationally.

The view of Indian scientists involved in the government's investigation of the accident is that the answer lies in contamination from corrosion. They believe the accident was just that—an accident—but that it was avoidable, and that the fault lay with the parent company, Union Carbide Corp.

"We have proof," says an Indian close to the investig[illegible]n, "that the process know-how and design provid[illegible] by Carbide were defective. Any other company in India purchasing foreign technology would have raised questions of why large quantities of stored MIC were necessary. UCIL could have asked something like that. But in this case, here is a plant owned by Carbide. The detailed design was Carbide's. Approval and acceptance of the mechanics and processing were done by Carbide before commissioning."

He goes on to itemize where the Bhopal plant design was deficient. "At the Institute plant, for example, there is an intermediate storage tank between the production and storage units. This is used for continuous sampling of the product. Second, the MIC storage tank in Bhopal was not equipped with safety instrumentation. Sound alarms and flashing lights go off if the pressure and temperature increase at Institute. There was no such warning system at the storage tank area in Bhopal. In addition, the chilling system was underdesigned. At the Institute plant, the storage tank itself has refrigeration coils. The Freon is circulated inside the tank. At Bhopal, the material was taken out and then returned. So the UCIL refrigeration system was underdesigned; the cooled MIC went right back into the tank, which was probably at ambient temperature most of the time. So it probably was never being chilled, even when the unit was on. I don't think the tank could have been cooled much below 15 °C."

Indian government laboratories are attempting to simulate the reactions that might have taken place, based on their own samplings of residues as their own check on Carbide's investigation. "We have taken samples of the tank's wall," says one source. "It's almost impossible to go in the tank now because it still contains highly lachrymating mixtures—trimers, dimers, isocyanates, dimethylurea, biuret."

S. Varadarajan, India's top scientist as director-general of the Indian Council of Scientific & Industrial Research, says he is worried about the safety of those working or living in the vicinity of MIC in the U.S. today. "I think that until the exact cause of the runaway reaction at Bhopal is explained," he says, "there should be a ban on shipments."

The medical results

One year after the disaster, Bhopal is one vast experimental ground of industrial toxicology. Every patient is in some sense a toxicological celebrity.

Figures on the total number who died are becoming less controversial by the month. Some activists are still holding out for a figure of up to 10,000, but their voices have quieted. Their claim has been that thousands of bodies were dumped by Army trucks anonymously in mass graves at sites some distance from the city. But no one has located any such graves and few families have come forward to register family losses beyond those reported months ago. So the term "more than 2000" is the best anyone can say. As it is, about 15 gas-exposed persons currently die every month in Bhopal, according to official state estimates. The figure is over and above the 250 or so normal monthly deaths in the colonies that were affected.

Medical studies are showing a bewildering array of physical and psychological problems among the affected. Children under 10, when asked to make drawings, inevitably put their crayons to crude depictions

disorders. Lots of women delivered prematurely, though the fetuses were usually normal."

Bisarya thinks the state medical establishment made a serious mistake by not taking systematic records of the affected people from the very beginning. The focus was too much on treatment and not enough on the careful recording of symptoms.

"Also, I would have expected more involvement from American scientists and physicians," he adds. "Several people I know from Los Angeles said they were willing to come and spend a year or two. They needed government grants to do that. But the U.S. provided no such help

"Legally, it would have been beneficial to have American scientists. If the case goes to court and our Indian scientists make a claim, Carbide will send in American scientists to rebut them. If we had Amen-

says. "At that time there was a lot of pressure on the medical community. Whatever supplies we gave were not acknowledged in writing. Then came the contro-ersy over cyanide. That led some people to believe that UCIL deliberately misled the medical community. I don't know what our doctors were telling people. But the accusation that UCIL withheld information on long-term effects does not make sense. The truth is that we were unable to communicate to them what they needed to know."

Volunteer health organizations are upset with the vernment because they feel Madhya Pradesh physi-ans continue to underplay the extent of damage to women. Rani Bang, a Bombay-based gynecologist, reported in March that of 55 studies of women, 94% developed gynecological diseases like leucorrhea, 79% pelvic inflammatory diseases, and 46% menstrual bleeding. "Lactation suppression, impotence in husbands, stillbirths, and abortions have been other effects," her report stated.

Says Anil Sadgopal, leader of the Bhopal Poison Gas Struggle Front: "We were unwilling from the very eginning to accept the ways government doctors were downplaying the extent of problems. On Dec. 27 Ishwar Dass, then health secretary, was declaring that only eyes and lungs were affected. The rest of the systems he said were normal. To us activists in the field, working with the injured, the statement was shocking. Our survey teams had established that almost every organ of the body was showing one or another affliction. Gynecological disorders in various forms were observed by our doctors. And they are still showing it now."

But although medical disputes continue, especially over cyanide toxicity, much of that strident period is past. N. R. Bhandari, superintendent of Hamidia Hospital, says women need reassurance as much as anything. He believes that publicity has been so intense a nd dangers to newborns that anxiety is common a ng pregnant women. Ultrasonic fetal monitors have helped calm some women "When they see their living baby on the screen, they feel reassured," he says.

The relief efforts

Much of the agitation that has roiled Bhopal over the past year—riots, police beatings, storming of the state government's offices, a takeover by the morcha of the Carbide factory grounds—was in response to the slowness with which the Madhya Pradesh government was responding to the needs of the victims and to Carbide's unemployed workers. A superficial look at the gas-affected area, however, leads a visitor to conclude that significant changes are taking place.

Uniformed children sit attentively in one-room shacks that serve as schools. Little assistance centers dot the colony, one providing counseling services for women, another dispensing high-protein bread. Small shops are opening with money either given by the government or loaned to the villagers by, yes, UCIL. Some new homes, built solidly of stone, are seen, contrasting sharply with the crude tin and burlap shacks that still predominate. In one sense, the gas-affected people are the new elite of Bhopal. Some of those who never had it so bad now have never had it so good and are the object of envy by the rest of Bhopal's poor.

Down Berasia Road, which divides the colony from the UCIL plant, the government has opened cottage industry training centers. In one, more than 100 women, many widowed, work at sewing machines, turning out garments that the state will distribute in the remote villages of Madhya Pradesh. A knitting operation was opened in October. Last month a hosiery production unit got started. Men are being trained in new work, including television repair

Dass, the Madhya Pradesh first secretary in charge of all relief operations, says the government has plans to build an export-oriented business that will produce fine products for the international market. Dass is a Ph.D.-holding organic chemist who long since has abandoned the lab for government service.

A person like him was needed, for through May, the situation was getting wildly out of hand in Bhopal. A drought was threatening the area's economy. Its chief minister, Arjun Singh, had left suddenly to take up duties as governor of Punjab. Because of the lack of leadership, relief measures were in chaos. Medical treatment and record keeping was a mess. The gas-affected people, led by the morcha, were demanding more medical, nutritional, financial, and community help. And the UCIL workers were getting restive by prospects of no work. May and June were marked by demonstrations and jailings of morcha and labor leaders, as the cyanide controversy began bursting into the headlines.

By May, the central government began intervening. The chief finance minister, V. P Singh, the most powerful general policy figure in the Gandhi government, visited Bhopal and promised to break the financial logjam. At the same time, the state's new chief minister, Motalil Vora, began paying surprise visits to the affected colonies, meeting with people to hear their grievances.

Says Dass: "The morcha was dissatisfied with the way the scientific bureaucracy failed to convey information on anything important to the people. A motley crowd led by leftists came together and took a confrontational position.

"June 25 was the watershed. Since then they haven't been able to consolidate. When I took charge, I felt that once the people see what we are trying to do, the agitational scene will lose its relevance. Such organizations do have a role to play. I told the demonstrators to try to take over the wards and take up some concrete activities like comprehensive care."

Carbide is attempting to inject a permanent presence in Bhopal's rehabilitation efforts, and Dass says its efforts are always welcome. It is funneling some money in by anonymous means and has established a trust fund of about $200,000, made up of contributions from Carbide's Indian and U.S. employees, to be used as a source of loans to survivors who want to start businesses. Clinics funded by UCIL are in operation. A leather products business has been started, funded by UCIL. The most ambitious project is a housing project that is currently going up

The future of the plant site is still being determined. Carbide offered to make batteries there, or reopen the pesticide formulation plant. But the government would have none of that. Carbide has a 99-year lease on the site for industrial operations at a yearly rental of $600 a year. It has no intention of giving up the land and probably will appeal any order to depart.

"We have all our buildings and plant on the site," says UCIL's Gokhale. "There is a sizable investment there." The future of the pesticide research lab on a hill overlooking Bhopal is also unclear. Morale is poor there. Several researchers have departed. The government has suspended its tax-exempt status. It could be nationalized, or closed.

Not everyone is satisfied with the relief schemes in Bhopal. Sadgopal's morcha continues to agitate for more input for the affected people. The Rashtriya Abhiyan Samiti, another of at least a dozen public interest groups that have settled in Bhopal since the disaster, is one of Dass' sharpest critics. The group calls Dass' rehabilitation scheme a "cruel joke" on the victims.

"Only the government and its experts can explain how an aerodrome, a railway station, a botanical garden, a boating facility, and a swimming pool are related to the rehabilitation of gas victims," it says in a statement. "The government has proposed an expenditure of [$85 million] on such irrelevant schemes. There has been no attempt to satisfy the needs of the 80% worker population of the gas-affected areas employed as railway coolies, day laborers, bidi (cigarette) makers, tailors, petty businessmen, textile and paper mill workers, railway gangmen and peons, whose health, housing, and employment have been seriously affected."

J. P. Nagar is the showcase of the affected communities. But at other areas such as Kazi Camp and Railway Colony, off the official Bhopal gas tour, the pace of recovery seems slower, though government clinics and those run by various voluntary groups keep open house in all the colonies. At the Railway Colony, stories tell of residents there being forced to pay for their own treatment and care, including trips to Bombay for special care.

The relief story in Bhopal will be a source of continuing controversy for perhaps years.

Thiosulfate/cyanide issue is most controversial

The issue over whether many of the Bhopal victims were and still are exposed to some form of cyanide poisoning is the most controversial aspect of the tragedy, and the most politically explosive. Indeed, as one Gandhi Medical College physician observes, "The cyanide issue is more sociopolitical than scientific." In the beginning, Madhya Pradesh medical officials and Carbide physicians denied any possibility of cyanide exposure among the gas-affected victims. Yet, on Dec 6, three days after the event, scientists of India's A Pollution Control Board were detecting cyanide at the MIC storage tank area and 50 meters downwind. At about the same time, doctors at Bhopal's hospitals were treating victims for cyanide exposure. (The presence of cyanide at the tank site is an intriguing notion, since the leakage was almost exclusively reported to be at the scrubber.)

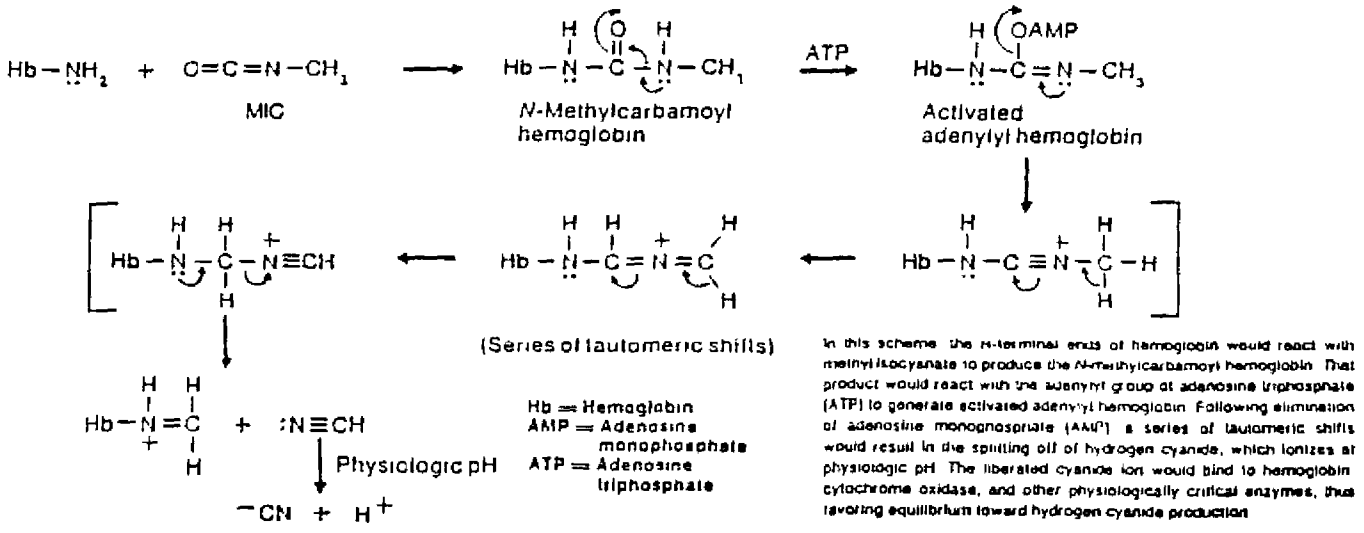
By February, the Indian Council of Medical Research finished its study of cyanide exposure and in a March report recommended continued sodium thiosulfate treatment. It said that, although there was no longer any direct exposure to cyanide, reactions involving the body's "cyanogen pool" and biochemical by-products of MIC could be accounting for the success of sodium thiosulfate treatment.

The report pointed to improved condition of treated patients and increased urinary concentrations of sodium thiocyanate after treatment, indicating the presence of cyanide in the system. Since sodium thiosulfate is a drug without appreciable side effects, the council said it would do no harm to continue treatment. Volunteer physicians were reporting permanent recovery in many cases from the treatment. But local doctors were by then opposing it, claiming that any positive results were due to psychosomatic responses. Patients, they said and say now, kept coming back for booster shots that really were doing no good.

"I feel that in the initial stages there was no doubt cyanide was present," says health services director Nagoo "The toxin that was fixed to the tissues could well have been cyanide. But a year later it is difficult to believe cyanide is present and could be detoxified."

The issue has taken on fierce political and social overtones in Bhopal, causing riots, beatings, and jailing of both morcha demonstrators and volunteer physicians. At one point last summer, police under orders

Proposed mechanism for generation of cyanide in the body after exposure to MIC



Source: Harold Teague, Pembroke State University

from Madhya Pradesh authorities, broke into thiosulfate dispensaries run by volunteer physicians, arrested them, and confiscated the thiosulfate supplies.

"The cyanide issue is important not merely for its biomedical/toxicological aspects," declares Bhopal leader Sadgopal, a biochemist who received a Ph.D. in 1963 from California Institute of Technology under James Bonner. "The real importance lies in the legal ramifications. To us it is important because a serious attempt would be made by Carbide lawyers to establish that a large portion of the lung damage can be explained by such things as endemic tuberculosis. It is at this point that the issue of cyanide toxicity would become crucial because if you can establish that so many thousands of people received clinical benefit from sodium thiosulfate injections and you have a clinical record, then you have established that they were suffering from cyanide or cyanidelike toxicity. If sodium thiosulfate gives relief, it is a specific antidote and its effect is shown by a specific chemical urine test for thiocyanate. High levels of it in urine would measure the amount of exposure."

What Sadgopal did manage to do, with the legal help of a Bombay activist lawyer, Indira Jaisingh, was to win an order by the chief justice of the Indian Supreme Court. The chief justice instructed the Madhya Pradesh government to allow the distribution of thiosulfate to volunteer groups, like the People's Medical Center, to continue their treatment. Sadgopal says his case was strengthened by Heeresh Chandra, chief pathologist at Gandhi Medical College in Bhopal. Chandra had been one of the first to detect symptoms of cyanide poisoning and to this day continues to insist that cyanide is still being generated in patients and that thiosulfate therapy is useful. What helped, too, were the March recommendations in favor of thiosulfate by Ramalingaswami's ICMR, which Madhya Pradesh physicians refused to act upon. In a development last month, Sadgopal and Jaisingh also convinced the chief justice to appoint Sadgopal and forensic scientist Chandra to a seven-member committee with direct oversight over the entire clinical program in Bhopal.

The cyanide issue, scientifically speaking, appears to have two aspects. One is direct exposure, which could have occurred during the first hours in the areas closest to the plant. The technical book on this one is closed, although the mystery of why exposure was so vehemently denied by officialdom isn't. The second aspect is indirect exposure owing to unusual generation of toxic amounts of hydrogen cyanide in the body after exposure to MIC.

"The way the ICMR scientists have explained the mechanism of cyanide generation makes some sense," says biochemist Sadgopal. "That is the concept of the body's cyanogen pool generating cyanidelike radicals continuously in the bloodstream. When released, they could hook onto the hemoglobin, or to some other enzyme, or to cytochrome oxidase (a key respiratory enzyme). They could either block the respiratory system at the cellular level or modulate the behavior of the hemoglobin in releasing or carrying oxygen.

"Now, the sources that feed into the hypothetical cyanogen pool could be many. One possibility could be MIC linked to a peptide or amino acid, which is gradually hydrolyzed by enzyme action. Then MIC could be converted into thioisocyanate by the transfer of sulfur from thiosulfate. Thioisocyanate existing in equilibrium with thiocyanate is one possibility."

The scheme, though general, does make some hypothetical biochemical sense. MIC binds to hemoglobin in a carbamylation reaction. That binding was a common clinical observation at Bhopal. (The isocyanate-hemoglobin reaction is used to some advantage

clinically, too. It is a well-known treatment for sickle cell anemia, because the reaction converts the sickled h- oglobin to a more normal shape.)

paper just submitted to the *Journal of Chemical Education* by organic chemist Harold Teague of Pembroke State University theorizes a series of reactions by which the MIC-hemoglobin combination could result in the generation of hydrogen cyanide. The reactions involve adenosine triphosphate and a series of electron shifts, resulting in the splitting off of hydrogen cyanide, which would then itself bind to hemoglobin. The success of thiosulfate therapy would then make some sense.

So scientifically, the cyanide issue is intriguing; politically it raises adrenaline levels; and legally it waits a final verdict as to its importance. Right now, it is no consideration in the current legal battle between Carbide and the government of India.

Chemical safety reform in Madhya Pradesh

If words alone are the criterion, Madhya Pradesh appears to be well along the way to cleaning up its industrial safety practices. In the aftermath of Bhopal, says Madhya Pradesh Labor Secretary S. C. Gupta, the first thing his department did was assemble a team of experts to undertake a quick survey of industries that handle chemicals in the state. The team surveyed 61 chemical units, found some deficiencies, and then suggested remedial measures.

\nother action was to give an assignment to Engineers of India Ltd., a design firm, to do safety audits of 11 industries engaged in the manufacture or use of chemicals," he says. "They inspected those units and gave interim reports and pinpointed the deficiencies that were detrimental to health and safety. We wanted to know whether they were detrimental to the health and safety of the workers and whether there could be dangers posed to localities.

"In another activity, the state has established a committee of senior secretaries to examine the question of setting down norms and procedures for ensuring the protection of villages situated in areas affected by the construction of pollution-prone industries. They have a large charter, covering steps for the approval of their operations on environmental grounds, criteria for site selection of major industrial complexes, and procedures for the regular inspection and certification of such facilities. The committee is also examining which parts of existing laws and regulations need to be modified or amended.

Gupta put together another team to examine the central government's Factories Act rules and regulations that directly relate to industrial health and safety. "We found certain lacunae," he reports. "If our inspectors were to find a certain deficiency in a unit, they had no power to suspend operations. There was no penalty for failure to carry out the recommendations. So we are suggesting that inspectors be given the power to revoke or suspend until deficiencies are rectified. The current penalties are no deterrent. They give three months to carry out improvements, plus a fine of only 2000 rupees."

The Factories Act does not obligate company management to keep communities informed of dangers, nor does it require preventive measures that could be taken. "Many of us did not know the UCIL factory could pose such a danger," Gupta says. "[Management] never mentioned anywhere whether any raw material was toxic. [It] had no obligation to tell us about any change in the process."

In New Delhi itself, reform of the Factories Act is under debate. The urge for reform certainly seems to exist in India, especially in the chemically developed areas around Bombay. The press is quick now to report leaks all over India. Each state has appointed independent inspection teams, trained in chemical engineering, to survey danger spots.

But although the Indian technical community is paying heed to the country's own deficiencies, it is also insisting that the West refrain from regarding the country as a technological backwater.

"Chemical accidents before and after Bhopal in the developed countries show that chemical technology is not necessarily managed more intelligently there," says chemist G. Thyagarajan, a Council of Scientific & Industrial Research laboratory director and head of the government's technical Bhopal investigation team. "Runaway reactions do not make a distinction between developing and developed countries. Did Flixborough [the 1974 chemical disaster in England] happen in a developing country? Did the Seveso poisonous gas leak occur in a poor developing country? Why did a toxic gas leak occur last August in a Union Carbide plant whose safety was said to have been beefed up by the spending of $5 million?"

There is no lack of scientific and technological talent and imagination in India. Indian scientists point to the giant government-owned Indian Petrochemicals Ltd. (IPCL) complex at Baroda that licenses western technology, and the privately owned National Organic Chemicals India Ltd. (NOCIL) pesticide plar at rural Chiplun, south of Bombay. Managers in thos plants all make the point of saying UCIL's operation at Bhopal was not representative of anything near what indigenous Indians can do. Discussions with Indian scientists, engineers, industrial management figures, bureaucrats, journalists, and activists all lead to that one point. The feeling is that Carbide bungled Bhopal badly. It was trying to push a product, Sevin, whose market potential in India was dwindling. It knew it, was hoping to sell off its Bhopal plant, and had virtually given up on it. The stage seemed set for disaster.

As far as the long-term effects of Bhopal on India's consciousness, even activists are pessimistic. Says Vijay Varma, a physicist at Delhi University, who is active in the reform of science education in Madhya Pradesh: "Bhopal happens and the general feeling is that it is an act of Providence, not likely to happen again. I think the West will learn from Bhopal more than we

Crucial court decision approaches in suits by Bhopal victims

It has been 10 months since most of the 119 lawsuits filed in the U S. on behalf of individual Bhopal victims against Union Carbide were consolidated in the U.S. District Court for the Southern District in Manhattan. Nearly eight months have passed since the government of India sued Carbide in the same court, and more than four months have elapsed since Carbide moved to have the actions dismissed on the grounds that the U.S. was not the proper forum for the case. Now, with much of the preliminary legal work completed, the stage is set for a decision crucial to all parties.

On Jan. 3, 1986, attorneys for both sides will present oral arguments on the dismissal motion to federal judge John F. Keenan, who is presiding over the proceedings, in the Manhattan court. Judge Keenan's ruling on the dismissal motion could come on the same day or after a period of consideration. It is also possible, though not expected, that the judge could request additional information before issuing his ruling.

Whatever the timetable, the future course of the case in the U S., and, probably, the tack of future settlement negotiations, hinges on the ruling. If the case remains in the U.S., Carbide could ultimately face American-scale damages, which are far higher than those generally awarded for personal injury in Indian courts. Therefore, legal experts believe, the company's bargaining position would be weakened and India could demand more money to settle its suit. On the other hand, a ruling for dismissal would strengthen Carbide's negotiation stance. Negotiations have been stalled, apparently awaiting the court ruling, since a reported $300 million offer by Carbide was turned down by the Indians last summer.

Key to the ruling is the judge's interpretation of the briefs and oral arguments in the light of forum non conveniens, a legal doctrine that can be used to determine whether the forum chosen by the plaintiffs is a suitable tribunal. Carbide's contention, under the doctrine, is that the actions should be moved to India because the disaster occurred there, the plaintiffs are all Indians living there, "essential" witnesses and evidence are located there, and many suits have been filed there. Underlying the company's point of view is its insistence that whatever liability may be involved should not include Union Carbide Corp., the parent firm, but only Union Carbide India Ltd. (UCIL), the company which operated the Bhopal plant and which is owned 50 9% by the parent firm.

Attorneys for the plaintiffs, on the other hand, have argued that the parent firm is responsible for the acts of its subsidiary Acceptance of that premise, they contend, means many important witnesses and much crucial evidence on the design of the plant and control of its operation are located in the U.S. And that, they say, makes the U.S. court the proper one.

Because Carbide holds that the parent firm is not liable in the case, it wanted to shield itself from discovery inquiries until after the forum issue was decided. The plaintiffs, conversely, argued that since the liability of the parent firm was critical to their contention that the case should stay in the U S., they needed a discovery period before final arguments on the dismissal motion were heard. Judge Keenan, looking for a middle road, allowed a limited discovery, under which only interrogatories related directly to the forum issue were permitted.

Most of the information learned in discovery will not be made public until the briefs are filed, but Bud G. Holman, Carbide's chief attorney, says his side's inquiries uncovered "an enormous amount of information favorable to Union Carbide." He asserts, for instance, that involvement of Indian engineers in the design and construction of the Bhopal plant was greater than previously thought. Michael V. Ciresi of Robins, Zelle, Larson & Kaplan, the law firm representing India, declines to comment on what his side learned from discovery, citing a confidentiality order by the judge.

At the same time that the legal watershed grows nearer, Carbide seems to be increasingly emphasizing the theory that sabotage, rather than an inadvertent action, was responsible for the accident. Lawyer Holman admits he has no direct evidence of sabotage, but says that getting the water into the tank "was so improbably inadvertent that our conclusion is that it was deliberate." He adds that the plant library contained information that would have been useful to a saboteur and that it was open to most employees.

Ciresi scorns the sabotage theory as "the product of a runaway imagination. They have no facts to support it," he says, "and they know it."

If Judge Keenan rules in favor of Carbide on the forum issue, the plaintiffs will have the right to appeal If the case is kept in the U.S., Ciresi says, the plaintiffs' attorneys will try to move it to trial quickly, with discovery cut off by the end of June, the summer for pretrial motions, and an opening trial date of Sept 1, 1986.

David Webber, New York

will here. As long as the government is doing the enforcing, the process will be too corrupted. The only meaningful solution is for independent experts to take over enforcement."

'en activist Sadgopal has second thoughts "It is amazing that we have not been able to explain the sociopolitical issues involved in the Bhopal tragedy even to the people of Bhopal—the role of the multinational, the kind of development model we have chosen, in which the use of such pesticides and highly toxic materials is allowed, or the character of science and technology as practiced in the country, or the suppression of vital medical and scientific information by Carbide assisted by our government

Gokhale is an especially dramatic figure, in some ways a character out of a Greek tragedy He wants his fellow Indians to know that his company has made every effort to demonstrate that the Carbide family

cares very deeply about the plight of Bhopal's gas-affected survivors. Legally, he asserts blamelessness. He defends the management of the plant. Corporately, he stands together with the U.S. parent company. The trouble is that the parent isn't standing together with him. The managerial blame has been placed on UCIL by Carbide in Danbury. The parent firm believes that because mistakes were made in Bhopal, and because UCIL had full managerial responsibility, then the case should be shifted to India. "Fifty years of contributions to Indian society seem to have disappeared after this tragedy," Gokhale laments.

So although Carbide and UCIL both believe that the place of trial should be India, no one really wants a trial. All parties, except for various activist groups who want to punish Carbide, would prefer an out-of-court settlement. But that has complications, too, over the worth of an Indian life. Indian government sources close to negotiations say India would accept something less than $1 billion distributed by a formula that would ensure upfront costs and support to those suffering long-term pathologies. In addition, criminal charges against both companies would be dropped those sources say.

There is a continuing vastness to the subject of Bhopal, one year after the calamity that so rocked the conscience of the chemical industry. The lesson then, as now, is that another Bhopal cannot be allowed to happen. Safety audits are the order of the day, in India and in the rest of the world. Workshops and symposia on industrial and community safety are densely scheduled. The chemical world has learned, because industrial disasters—so enormously wasteful of money, human energy, and long-built reputations—do teach. □