Ethics Case Study: The Bhopal Tragedy

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Introduction

During the night of December 2nd and 3rd 1984, a leak of some 40 tons of methyl isocyanate (MIC) gas mixed with unknown other gasses from a chemical plant owned and operated by Union Carbide (India) Limited, a partly-owned subsidiary of the US-based Union Carbide Corporation, caused one of the highest-casualty industrial accidents of the 20th century. At least 2,000 people died immediately and another 200,000 to 300,000 suffered respiratory and other injuries of varying severity. Property damage consisted mainly of contamination to nearby areas by various chemical residues. The defoliation of trees immediately afterward is clearly attributable to the gas leak; contamination in the nearby settlements may have multiple sources, the contamination of the plant site resulted from many years of general production activity.

Industrial disasters and natural disasters do not occur under similar circumstances. A natural disaster is a single event over which no human being has control. But an industrial crisis is a complex system of interdependent events and involves multiple, conflicting stakeholders. This is an accurate description of what happened in the Bhopal tragedy. A series of human actions lead up to the final “triggering event” – the gas leak – that created the worst industrial disaster in history. This course seeks to present the technical actions and decisions that led up to this disaster, although a complete accounting of the events may never come to light because the survivors and their advocates, Union Carbide Corporation (UCC) and the Indian Government all have their own versions of what happened and doubtfully will ever change those views.

Need for Pesticides

In the 1970’s, the crops in India were being destroyed by insects, increasing the hunger and poverty of millions of peasants dependent upon the yield of their crops for both income and personal sustenance. The government of India, seeking to increase the industrial capacity of the country, agreed to license the American company, UCC, to manufacture its insecticide Sevin in India. The UCC representative behind this deal, an experienced sales executive named Eduardo Munoz, calculated that the maximum amount of annual Sevin sales would be two thousand tons. However, the license was for five thousand tons and the Union Carbide management - who had no experience with the Indian population - insisted the plant be designed to produce this amount of insecticide. The way the company compensation schedule was designed, they would be paid more with a bigger plant. Even the project's chief engineer supported this plan.

Construction of a Pesticide Plant in Bhopal

The insecticide Sevin, considered a safer replacement for DDT, was currently being manufactured at UCC's Institute plant near South Charleston, West Virginia. A team of engineers from this plant, familiar with the dangers of the highly-toxic chemicals that would be made during the production process, was assigned responsibility for the design and opening of the plant. Engineers from India worked with American engineers. Employees from India were sent to West Virginia to train at the Institute plant. *Safety First* was a motto of Union Carbide that was imparted to these trainees, mainly through a 400 page manual in English with detailed instructions for responding to emergencies. However, to save money, the final design, released in 1972, did not include all the same safety and security precautions featured at the Institute plant in West Virginia. While the plant at Bhopal was supposedly designed using the same process as the Institute plant, more recent evidence has indicated that the plant at Bhopal was actually using an "unproven technology" for MIC processing.

American engineers from South Charleston went to India to monitor the construction and start-up of the plant in Bhopal to be run by Union Carbide India Limited (UCIL). Union Carbide Corporation owned just over 50% of UCIL. The plant was seen as a great blessing by the people of the area, especially those living in extreme poverty in massive shantytowns, known locally as bustees, adjoining the acreage where the plant was later built. The plant paid the highest wages in the state of Madhya Pradesh. Experienced process engineer Warren Woomer was sent to Bhopal to run the new plant. He stressed safety, especially "the MIC manual with its forty pages of instructions" and stressed "only stock a minimum quantity of methyl isocyanate on site." This is the chemical known as MIC.

Early Accidents

The first fatalities from the plant were five cows living in a nearby bustee – cows are not only sacred in India but a health and economic asset. They were poisoned from water flowing from the plant. The community well was also contaminated. UCC reimbursed the villagers for the deaths of the cows. The report on the well water was too unfavorable to release, and the well was left alone.

The first human death at the plant occurred when Mohammed Ashraf, an experienced maintenance operator in the phosgene unit, was changing out a defective flange. The plant was not running so he assumed there was no chance of a leak and did not wear protective clothing. He was wrong. Some of the chemical leaked onto his clothes. He jumped in the shower but removed his mask before the chemical had been all washed away. He died an agonizing death two days later, leaving a wife and two young sons. UCC defined this incident as a breach of the safety procedures that the deceased had been trained to follow but also stated that “it must never be allowed to happen again.” A third accident occurred when a joint in a MIC pipeline broke during maintenance, releasing the highly toxic gas. The plant was evacuated. The wind was not blowing towards the shacks in the bustees.

Cutting Costs

In May 1982, three American engineers from the Institute plant inspected the plant at Bhopal and found over 60 violations of safety and security regulations. The engineers at the Bhopal plant reviewed the report with great concern. Unfortunately their safety conscious leader, Warren Woomer, was being sent back to the US. To satisfy “the complete Indianization of all foreign companies” in India, an Indian with “an impressive academic and professional record", including engineering degrees from Cambridge University and MIT, Jagannathan Mukund was taking over the position of running the Bhopal plant. He was to report to a higher manager, D. N. Chakravarty, whose sole task was to cut costs. Chakravarty was a chemist but his experience was in battery manufacture, not in a plant full of highly-toxic chemicals. His cuts caused one of the chief Indian engineers at the plant, Kamal Pareek, to later reflect “we knew the plant was inevitably going to hell.” Maintenance schedules were lengthened. Stainless steel was replaced with carbon steel. Pareek mourned “My beautiful plant was losing its soul.” Ranjit Dutta, one of the original engineers to work on the Bhopal plant project, returned to Bhopal from where he was now working in America as a VP at UCC, and visited the plant. The site was in disarray. He tried to alert his superiors at UCC but they ignored him.

Five of the issues cited by the American engineers in this report and not remedied by UCIL eventually contributed to the fatal gas leak:

1. The potential for release of toxic materials in the phosgene/MIC unit and storage areas because of equipment failure, operating problems, or maintenance problems
2. A lack of fixed water-spray protection in several areas of the plant
3. The potential for contamination, excess pressure, or over-filling of the MIC storage tank
4. Deficiencies in safety valves and instrument-maintenance programs
5. Problems created by high personnel turnover at the plant, particularly in operations

A Plant in Decline

India's agricultural problems began to subside as government-supported agricultural improvements lead to a surplus of food that could be transported to all parts of the country through improved transportation and distribution systems. Cheaper pesticides were available from smaller manufacturers. While the plant had never produced more than 45% of its capacity, by 1984 UCIL's Bhopal facility was producing less than 1,000 tons, less than 20% of its capacity.

By the fall of 1983, after Chakravarty left, the factory was on a downhill slide. Production was on an as-needed basis. Then Mukund made the decision to "shut down the principal safety system... because the factory was no longer active, these systems were no longer needed. No accident could occur in a factory that was no longer operating." Part of this shutdown included saving minimal costs by no longer refrigerating the MIC tanks -- the refrigerant was later pumped out of the system and used elsewhere in the plant. UCC's safety standards were adamant that these tanks should be maintained at 0^{o}C.The flare tower was also taken offline as was the decontamination scrubber. This last of round of changes was too much for many of the engineers who had been with the plant since the beginning. By this time, half had already left. Finally one of the first and most dedicated, Kamal Pareek, left but not without first activating all refrigeration system to cool the three tanks of MIC down to 0^{o}C. The working environment of the Bhopal plant tolerated negligence and a lack of safety consciousness among workers and managers. Employee morale was low because the plant was losing money and being considered for divestment.

Warning Signs

During the five years preceding the Bhopal disaster, there were twenty-eight major MIC leaks at the Institute plant in West Virginia with one releasing 7 tons of a MIC/chloroform mixture a month before the Bhopal leak. In a document dated September 1984, Union Carbide was alerted to a series of defects at the Institute plant that put the employees' safety at risk. The Bhopal plant was modeled after this plant. The document also described how a MIC leak could occur due to the presence of these defects. One factor was "miniscule impurities" produced by the refrigeration system that could trigger a reaction in the MIC tanks. Similar impurities could come from the flare tower. This information was not sent to Jagannathan Mukund, the director of the Bhopal plant.

The three underground MIC tanks were kept pressurized using nitrogen gas. This pressurization allowed the MIC to be pumped out of the tanks when needed for production and also kept out contaminants. On

October 21,1984, the pressure in MIC tank E610 dropped from about 1.25 kg/ sq cm to about 0.25 kg/cm. This tank contained about 42 tons of MIC that had been manufactured earlier that month. Because of the low pressure, MIC could not be pumped from this tank for production and had to be taken from tank E611 instead. Then on November 30th tank E611 also lost pressure due to a defective valve which was replaced. Tank E610 was not repaired. The lack of nitrogen pressure was later found to have allowed metal impurities into the tank which contributed significantly to the later disaster.

The Disaster

On the evening of December 2, 1984, Tank 610 was almost full with 42 tons of MIC, Tank 611 contained 20 tons and Tank 619 contained one ton, although safety standards specified it should be empty. Now, even though winter in Bhopal, the lowest expected ambient temperature was only 15°C. The tanks were not being cooled so the internal temperature was around 20°C. This amount of stored MIC was in violation of all UCC safety standards, as was storing it above 0°C.

While there appears to be no argument that water in the MIC tanks contributed to a runaway reaction that lead to the gas leak, there is not a consensus on how the water got into the tanks. Union Carbide maintains that the water was put into the tanks as an act of sabotage by a “disgruntled plant employee, apparently bent on spoiling a batch of methyl isocyanate.” However, Union Carbide has not named or pressed charges against this individual.

A second and apparently more widely reported version of what happened that night is that an operator accidentally pumped water into the MIC tank during a routine maintenance. This version begins when second shift operator Rahman Khan was told to flush out some pipes with water. These pipes had developed “a plastic substance called trimer” that was created when MIC reacted with water. Khan was still new and not familiar with this task but followed instructions left by another employee, only these instructions had one step missing – he needed to put in solid discs called slip blinds to block the flow into the MIC tanks. He began flushing the pipes, and noted this in the logbook before leaving at the end of his shift. According to reports, the maintenance supervisor was responsible for ensuring this maintenance procedure was properly performed, including the insertion of the slip blinds, but this position had been recently eliminated for both second and third shifts. A third theory to explain water in the MIC tank is that a well-intentioned but poorly informed and panicked employee poured water into the tank in an effort to cool down the MIC tank that was already exhibiting problems.

Regardless of who was responsible for the water entering the tank and why, hours of water pouring into the tank contributed to a reaction that was out of control. A third shift operator noticed the pressure going up in Tank E610. Unfortunately he was unable to obtain a temperature reading due to a faulty circuit that had not been repaired. His supervisor insisted that there could not be a problem because the plant was not in operation, even ignoring the first smells of boiled cabbage, the characteristic odor of a MIC leak. Not until he saw a geyser erupting from a broken pipe did the supervisor believe this was possible. At this point he sprang into action, trying to bring the fire department in to spray the geyser and neutralize it, but they were unable to access it. If a sprinkler system recommended by the three American engineers had been installed then it could have done the job. The single flare tower was not available due to maintenance – it was missing a length of pipe. The scrubber was decommissioned. And the wind was blowing towards the bustees.

The lack of nitrogen pressure in Tank E610 allowed “metal impurities” into the tank from the nitrogen line as evidenced by samples taken during the investigation. These metal impurities are thought to have served as a catalyst for a “self-accelerating trimerization reaction.” The high temperatures from this primary reaction then lead to the secondary reaction that created the toxic chemicals. The amount of water pumped into tank E610 alone was not responsible for the speed and intensity of this reaction.
In summary, the following events were identified as leading up to the accident:

1. The number of operators manning the MIC unit was cut in half between 1980 and 1984.
2. Operators had inadequate safety training.
3. Managers and plant workers had little information on the hazard potential of the plant, and there were no emergency plans.
4. When storage tank E610 failed to pressurize on October 21, 1984, managers did not investigate the causes of the failure.
5. Operators failed to put in the slip blind to prevent water from entering the storage tank during the flushing operation.

Chiles describes how a system fractures similarly to metal, beginning with very small cracks that continue to grow and spread unless someone makes an effort to stop the failure. Every time the cracking hits another weak point, the spreading accelerates. Failure of a system can be viewed as a progression of cracks from weak point to weak point. This description of system failure can be seen at Bhopal. The impending failure slowly progressed with microscopically small cracks in the system as management cut safety systems and decreased both the number and training of the maintenance workers. Then when the reaction in the MIC tank began to run out of control, the failure accelerated with more apparent symptoms as the systemic cracking began to spread to its disastrously weak points - the unavailable safety features.

After the disaster, engineer Warren Woomer returned to Bhopal. There was still MIC in the tanks. How could they dispose of it? Woomer had the solution – convert it to Sevin. The plant was brought back into operation and, amidst a political circus, the remaining MIC was converted to Sevin.

Making Process Plants Inherently Safer

In the last decades increasing attention has been paid to the topic of responsibility in technology development and engineering. The topic is often raised in the context of disasters due to technological failure, such as the Bhopal disaster, the explosion of the Challenger, and the sinking of the Herald of Free Enterprise. The discussion of responsibility then typically focuses on questions related to liability and blameworthiness. Asking these questions might suggest that there is one, unambiguous definition of responsibility. This is far from true, however. In moral philosophy, few concepts are more slippery than that of responsibility. What the questions of liability and blameworthiness share, is that the question of responsibility is asked after some undesirable event has occurred. However, the ascription of responsibility can also refer to something that ought to happen in the future: being responsible then means that an agent has been assigned a certain task or set of obligations to see to it that a certain state of affairs is brought about (or prevented). In that latter case, responsibility is often ascribed from a consequentialist perspective. As a third approach one could also distinguish the question of responsibility from the perspective of the rights of potential victims, which often focuses on the question who should put a situation right (e.g., by compensating for certain damage).

Recent discussions in engineering ethics call for a reconsideration of the traditional quest for responsibility. Rather than on alleged wrongdoing and blaming, the focus should shift to more socially responsible engineering, in which ‘‘to maximize the service to the larger society’’ should become the ethical norm. Responsibility as blameworthiness should therefore be replaced by, or complemented with the notion of engineering as a responsible practice. Until the late 1990s, scholarly literature on engineering ethics, however, seemed to be biased towards the blame-oriented or merit-based perspective on responsibility rather than this more forward-looking perspective. As professional engineers ethically dedicated to protecting the safety, health, and welfare of the public as well as protecting the environment for future generations, the need for safer process industries is clear. Process plants can be dangerous places. We work with energy products and chemical transformations that are driven by energy, and often hazardous substances or conditions must be employed. The fuels and industrial chemicals we use can be hazardous: fuels burn readily, with the release of energy; chemical reactions often involve large amounts of energy; and reactive chemicals can harm people and the environment.

Making a refinery or a chemical plant “inherently safe” may not be possible, but plants often can be made inherently safer through an approach pioneered by Trevor Kletz in response to the 1974 tragedy in Flixborough, England.

A New Approach

Prior to 1977, the approach to process safety was to control hazards via improved procedures, additional safety interlocks and systems, and improved emergency response. Kletz proposed a different idea: Change the process to eliminate the hazard completely, or reduce its magnitude sufficiently to eliminate the need for elaborate systems and procedures. His insights eventually led to what are now the four basic approaches to inherently safer processes.

1. Minimize

The first of the four approaches is to simply use smaller quantities of hazardous substances (a technique also called intensification). The facility in Bhopal had a large inventory of MIC, which is an intermediate chemical, was kept in tanks for convenience in operation, even though the plant was shut down at the time of the tragedy. During the plant shutdown and against safe practice, water entered a large MIC storage tank, possibly due to a leaky valve during cleaning of connected pipe work. The water reacted with the MIC, causing an exothermic (heat releasing) reaction. As a result of the heat release, the MIC boiled in the storage tank and MIC vapor vented through the pressure relief valve on the tank. During normal operation, the vapor from the pressure relief valve would be piped to a scrubber or to a flare, thus preventing an atmospheric release of MIC. However, the scrubber was not operating, and the pipe to the flare had corroded and been removed for replacement.

The Bhopal tragedy was a watershed event for the process industries and a wake-up call. In the US, one manufacturer was operating a plant that had been importing tank-car quantities of MIC from another US plant over a distance of 1,200 miles. Recognizing the potential hazards of shipping MIC, within six months after the Bhopal disaster the plant had installed a new process in which MIC was made at the site, eliminating the need to import it. In this process, the MIC was immediately reacted with 1-napthol to form the desired crop-protection product. Now, the new process never has more than a few pounds of the MIC intermediate in the plant at one time, and the plant has operated without any MIC releases since then.

2. Substitute

Replacing a hazardous substance with a less hazardous material is the second approach to inherently safer processes. For example, transporting and using aqueous sodium hypochlorite (bleach) may be safer than transporting liquefied chlorine under pressure. (In this case, however, more truck loads may be needed, so the entire supply chain should be examined.) The production of acrylonitrile, which is used in the manufacture of plastics, provides another example. The hazardous route involves combining acetylene and hydrogen cyanide, which both are highly flammable and explosive under the wrong conditions. Hydrogen cyanide is also very toxic. A less hazardous route uses propylene, ammonia, and oxygen to produce acrylonitrile. Although propylene is flammable and ammonia will burn, explosion and toxicity hazards are much less with this route. The dilapidated premises of the infamous Union Carbide plant stand as a reminder of the 1984 tragedy that killed at least 3,000 people and caused many more to suffer permanent health problems.

3. Moderate

Creating an inherently safer plant can also be accomplished by using less hazardous conditions, a less hazardous form of a material, or facilities that minimize the impact of a release of hazardous material or energy (also called attenuation).

In the case of ammonia, which has numerous industrial uses, diluting it with water can create a safer environment. Anhydrous (100%) ammonia at typical ambient temperatures must be stored in pressure vessels (at 21 degrees C, the vapor pressure of anhydrous ammonia is 8.8 atmospheres). If containment is lost, the ammonia will quickly vaporize, forming a toxic and potentially flammable vapor cloud.

If ammonia is diluted with water to a concentration of 19%, however, the partial pressure of ammonia at typical ambient conditions is much less than one atmosphere. Therefore, the aqueous ammonia will not boil and form a large vapor cloud if containment is lost.

Similarly, the use of a lower temperature for storage of chlorine can create a safer environment. The lower temperature reduces the vapor pressure and can greatly decrease the size of any vapor clouds formed on accidental release.

4. Simplify

Kletz's final rule is to design facilities that eliminate unnecessary complexity, make operating errors less likely, and are forgiving of errors when they happen (also called error tolerance). For engineers, this could mean using welded, not flanged, piping for highly toxic chemicals and designing vessels to withstand full vacuum to prevent collapse during vacuum conditions.

Other Inherently Safer Methods

In addition to Kletz's four steps to inherently safer processes, three additional approaches are proposed here that deserve attention.

Hybridization: This method involves maintaining the original chemistry of the reaction but adding an additional chemical that transforms a potentially hazardous reaction process into a much safer one. This concept is based on work by Jenq-Renn Chen presented in a 2004 article in Process Safety Progress. Chen reported that adding water to cyclohexane decreased the flammability of oxygen/cyclohexane vapors without adversely affecting the basic cyclohexane oxidation process. This innovation prevents combustion from occurring in the gas phase in a gas-liquid reaction.

Stabilize or ensure dynamic stability: Not all process designs are inherently stable, but stable operation is achieved using instrumentation and controls. Modify the process design so that it has wide operating limits and is less sensitive to variations in operating parameters. One example of this approach is to increase the rate of heat removal from a strongly exothermic reactor in a way that prevents runaway reactions.

Limit hazardous effects during conceptual and detailed engineering: Increase the spacing of process equipment and of potentially hazardous units to reduce the likelihood, severity, and consequences of vapor cloud explosions and other overpressure incidents.

The Path Forward

Inherently safer design is now a recognized and generally accepted good chemical engineering practice. It should now be standard practice to apply this approach in design, construction, operation, and maintenance of process plants. How?

- When planning to produce a new fuel or chemical product, examine alternative products and alternative process technologies to get the best inherently safer results.
- Review process design early in the creation or modification of a process plant to ensure that opportunities for inherent safety are incorporated. This can be done by a separate inherently safer review of the process or by incorporating the inherently safer concepts in the process hazards reviews during the design process.
- For existing process plants, look for inherently safer applications when doing the periodic reauthorization process hazards analyses.

It is also important to remember that although it is easier to design for inherent safety than to retrofit existing plants, one can still improve older plants by modifications to incorporate inherent safety principles and practices.

As professional engineers, we are obligated to be ever mindful of safety, and we have the opportunity to continue to incorporate inherently safer design, construction, and operation. One need look no further than the new generation of process plants that will be built in response to abundant new sources of natural gas and oil from shale.

When designing these new facilities, comprehensive process safety management programs will be necessary, and inherently safer design will play a very important role.

Methods of Reducing Process Risks

To prevent process plant incidents, there are four basic risk management strategies:

Inherent safety: Eliminate the hazard by using materials and process conditions that are nonhazardous.

Passive safety layers: Minimize the frequency or the consequence of any hazard by a design feature that does not require the active functioning of any device, for example, dikes and blast walls.

Active layers of protection: Use controls, alarms, safety instrumented systems, and mitigation systems to detect and respond to process deviations, and for example, a control loop that shuts off feed to a reactor when an abnormally high temperature is detected in the reactor.

Procedural safety layers: Use policies, procedures, training, administrative checks, and emergency response to prevent incidents or to minimize the effects of an incident.

In recent discussions with engineering professionals at a large research and development firm, engineers (both managerial engineers and non-managerial engineers) note that engineering team players need to know all the particulars associated with the problem at hand. This includes budgetary and time constraints, promises made to clients, and realistic assessments of technological flaws.
Risk management is perhaps the most important aspect of the engineer's professional tool kit. It is important for the public, our corporations, and for the engineering profession at large. Managers and engineers approach risk in different ways. Managers have to factor in such things as schedules, budgets and contract requirements. Engineers tend to place safety considerations above all others. Engineers need more training in balancing risk versus benefit, so they can better communicate their legitimate concerns about public safety. For both managers and engineers alike, the likely tendency is to look at their work through a microscope, and, accordingly, not to see the many complications that fall just outside the field of resolution we are viewing.

Microscopic vision is enhanced vision, a giving up of information not likely to be useful under the circumstances for information more likely to be useful. If a point of light at the other end, microscopic vision is like looking into a microscope at things otherwise too small to see. Microscopic vision is a power, not a handicap, but even power has its price. You cannot both look into the microscope and see what you would see if you did not.

Thus, risk management programs force us to look up from the microscope, so we are better equipped for avoiding tragedies due to failed innovation. The decision-making process is never an easy one. The important thing all engineers must remember is that their first obligation is to public safety. Some risk is unavoidable. Engineering professionals must learn how to convince their managers that minimizing that risk is worth the effort involved.

Negligence and the Codes of Ethics of Professional Societies

What guidelines do the professional codes of ethics give engineers? The new IEEE code, for example, references the public's welfare, and the responsibility of engineers to inform all affected parties of any inherent dangers or risks. This is very different from engineering codes of ethics written in past decades, where the primary concern was competitive bidding, advertising, obligations to employers and clients, and so on. While these are all important issues for professionals, they are less important than obligations to the public and those obligations implicit in the engineers' adopted social contract.

In their recent book on engineering and ethics, Mike Martin and Roland Schinzinger cite earlier studies on the responsibilities of engineers. They summarize these responsibilities as involving the following considerations:

1. A primary obligation to protect the safety and respect the right of consent of human subjects.
2. A constant awareness of the experimental nature of any project, imaginative forecasting of its possible side effects, and a reasonable effort to monitor them.
3. Autonomous, personal involvement in all steps of a project.
4. Accepting accountability for the results of a project.

Martin and Schinzinger's implicit assumptions are that: a) engineers are and should be held responsible for past actions; b) engineers are responsible for the roles they have played in projects; c) engineers are capable of making moral (and certainly technically correct) decisions autonomously; and d) as such, each individual engineer is accountable for the projects she/he works on. Thus, an engineer can be deemed negligent if she/he does not meet these criteria.

The Ethical Issues of the Bhopal Tragedy

The nature of the disaster at the Bhopal site raises several questions relative to the engineering canon of ethics and whether or not the engineers and other professionals involved with the facility had obligations or responsibilities to protect the health and welfare of the public and facility personnel. The answers to these questions are not always black and white, and professionals familiar with ethics do not agree on the proper course of action. Questions that arise as the details are reviewed include:

Why were these Ethical codes broken?

How can we prevent future disasters of this type?

Several pertinent standards of care that engineers must follow arise as we evaluate the incidents related to the Bhopal incident.

“Hold paramount the safety, health and welfare of the public.”

At the Bhopal facility, poor quality and lack of many instruments, safety equipment and reduced operation of critical systems contributed to release of toxic gas. Critical systems, such as the flare tower, VGS, water sprays, MIC refrigerator, and Tank 610, were either offline for maintenance or had been decommissioned by plant managers. Did engineers involved with the project who were aware of these issues have a responsibility to act? Legally, they did not, but, in terms of their ethical obligations, the answer is not as clear. Further, the local community was never given any information about MIC and other chemicals being used at the facility. Did the local residents have a right to know that dangerous and lethal substances were being stored within sight of their homes? In the United States, community right to know laws require facilities to disclose this information. In India, this was not the case. Despite being compliant with national laws, were the engineers released from an ethical obligation to notify the public?

“Perform services only in areas of their competence”

At the Bhopal plant, jobs were continually cut to reduce costs and some shifts only had 8 workers despite the need for as many as 20 per shift. In addition, many workers lacked the expertise required for their positions, especially after the US engineers were no longer present. This was further compounded by a reduction in training from 6 months to 15 days for critical staff. Although many of the engineers who were involved in the project had moved on, others remained peripherally connected to the facility and were aware of these issues. What was their obligation to intervene and improve the plant’s safety by increasing the level of staffing and the training they were provided? Is it reasonable to assume that professionals working in another country with no direct involvement in the Bhopal facility should have stepped in to address their concerns?

"Issue public statements only in an objective and truthful manner."

"Avoid deceptive acts."

Prior to the tragedy, the facility experienced several smaller releases of dangerous and toxic chemicals. Affected workers sometimes went for random medical examinations, but were never told the truth about the risks to their health. The Chief Medical Officer of UCIL told doctors who were treating victims that MIC was a non-toxic irritant. Police officials were told lies by UCIL managers. Many false claims and accusations were made at trial by company representatives. Although engineers were not involved in these deceitful acts, in many cases they were aware of the untrue statements and lack of full disclosure. What obligation did they have to set the record straight and provide a full accounting of the facts and risk to the public health and welfare? Should engineers be held accountable for the actions of others in these situations?

Impacts and Final Analysis

Though there was defoliation of trees and some additional contamination of soil and lakes, the main impact of the accident was death and injury to humans and animals. Estimates of the number of immediate human deaths caused by the Bhopal gas cloud wary from the official Indian government figure of approximately 2,000 to the 10,000 favored by local activists. The number treated for gas exposure and continuing to suffer ill-health over the next several years has been estimated at 200,000 to 300,000, and by 1990 when the government of Madhya Pradesh provided the Supreme Court of India with a list of victims eligible for compensation, 3,818 persons were listed as dead from the effects of gas exposure. Additional thousands were made sufficiently ill to be unable to work. Medical treatment of survivors was complicated by lack of knowledge about what gasses escaped the plant, the paucity of information provided by Union Carbide and UCIL, the general lack of information about the long term (as distinct from immediate) effects of high exposure to MIC or related gasses, and uncertainty about what toxic chemicals other than MIC had poisoned the victims. The deaths also led to considerable disruption of family lives as widows and orphans joined households of relatives. Since most of these households were very poor, the strain of extra mouths to feed was considerable, particularly for families taking in survivors who needed continuing medical care.

Locally and globally, blame for the accident was quickly assigned to Union Carbide. Though it was clear immediately that Union Carbide and/or its executives would face criminal and tort charges in India, investors imposed penalties far more quickly. Standard and Poors dropped the company's credit rating to the lowest investment grade while institutional investors dumped enough shares for their stake in the firm to decline from 65 to 35%. Victims filed lawsuits against both the company and the Indian government (citing its failure to regulate effectively) in India and the USA during early 1985. Efforts to negotiate a settlement continued, with the Indian Supreme Court pressing the sides to come to a global settlement of all cases. They agreed on compensation of $470 million, a settlement panel of the Indian Supreme Court approved and ordered the parties to carry out.

For anti-corporate and anti-capitalism activists, “Bhopal” has become shorthand for corporate greed and callousness. For the victims and their supporters, the word conjures up continuing inaction by their own government as well. The accident also inspired considerable discussion of need for better regulations addressing chemical plant safety, information about toxic chemicals, and contingency planning for mitigating the impact of gas leaks inside and outside plants. In Western Europe, this process was well advanced in reaction to the 1976 Seveso gas leak in Italy. Policy initiatives were more numerous in the USA, particularly after a significant leak from Union Carbide’s MIC plant in West Virginia in early 1985 sent local residents to the hospital. Reaction was less strong in India, where environmental law was less developed and citizen environmental movements weaker. The problems found in the Bhopal disaster may be found in other manufacturing facilities, and for the engineering profession, it is hoped that by studying this incident future disasters can be prevented or minimized.