The Bhopal tragedy: its influence on process and community safety as practiced in the United States

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Abstract

The chemical accident at 12:45 AM on December 3, 1984 in Bhopal India had a profound effect on the practice of chemical process safety in the United States. Fearing the possibility of similar events occurring in the United States, the United States Congress convened several hearings and investigations into the causes of the disaster. The inquiries focused both on the state of process safety within the US chemical industry and on the readiness of communities located near chemical operations to respond to sudden and dangerous toxic discharges. Of equal significance were concerns over the safety of workers in chemical plants. This paper reviews the major legislative, academic, and industrial changes initiated in the area of process safety after the event, their influence on saving lives, and on improving living conditions surrounding chemical complexes in the United States.

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1. Introduction

1.1. Bhopal’s immediate aftermath: media coverage of the disaster within the USA

News of the disaster reached the front pages of all national news media approximately 36 h (4 December 1984) after the disaster struck. It became the lead story on the national television and radio newscasts on the same day. The initial New York Times, 1984 (NYT) headline in the 4 Dec 1984 issue read, Gas Leak in India Kills at Least 410 in City of Bhopal—12,000 reported injured—Officials say the fumes came from insecticide plant of US-owned company. NYT prominent headlines 2 days before the accident included: ‘Medication in Chile Temned Essential by US Officials,’ and ‘When Terror Threatens what the US Has Learned.’(New York Times, 2 Dec 1984). The page one photograph featured King Hussein of Jordan visiting Egypt. However, none of these headlines would cause the stir US public activism similar to the December 4th headline. The ‘silent majority,’ a term to characterize the bulk of the US citizenship’s apparent lack of participation and concern for major events of the day, woke up. Many international headlines appear in the media daily that do not lead to a public outcry or congressional hearings. The event in Bhopal on 3 December 1984 did.

Over the next few months at least 50 additional articles appeared in the New York Times. Time and Newsweek carried multi-page articles on the accident in their 17 December 1984 issues. Time devoted 10 pages (roughly 1/10th of the entire issue) to the accident. Many publications featured the horrors of the tragedy on their covers. The 17 December Newsweek cover and the magazine’s companion article both expressed what was the obvious question of concern to Americans: ‘Can It Happen Here?’

The first news story in Chemical and Engineering News (a weekly professional publication published by the American Chemistry Society) appeared in its 10 December issue. Headlines were: ‘Bhopal,’ ‘India’s Chemical Tragedy: Death Toll at Bhopal Still Rising,’ (Heylin, 1984) and a week later ‘India’s Bhopal Disaster: Chemical Mishap Raises Thorny Issues,’ (C&E News, 17 Dec 1984).

In Business Week’s 17 Dec 1984 issue (p32), US Representative Henry A. Waxman (D-CA), was quoted as...
saying: ‘This nation faces a quiet but deadly crisis. The public would not have to live in fear of nearby industrial facilities if the EPA met its responsibility to assure that everyone in a community is safe’. In Business Week’s next issue (24 Dec 1984 p60) Representative Waxman said he was considering proposing changes in the Clean Air Act to give the EPA the responsibility for setting standards for chemical plant safety and for overseeing companies emergency planning. Waxman and US Representative James J. Florio (D-NJ) scheduled hearings in Charleston, WV for December 14, 1984.

Meanwhile, Business Week was reporting that labor unions, with strong support from local citizen groups, were leading the drive for Community Right-to-Know legislation. The Reagan administration had been placing low priority on this legislation, despite previous chemical events within the United States that were raising public concern over the dangers of toxic chemicals and dangerous chemical operations. These included the ‘Love Canal’ incident in which toxic chemicals had been dumped into an abandoned canal near which residential housing and schools were subsequently built (see http://history.sandiego.edu/gen/nature/lovecanal.html); dioxin contamination at Times Beach, Mo (see Ref. EPA-1, 2004), Agent Orange exposure of Vietnam Veterans (Business Week, 24 Dec 1984, p60) and a release in Linden, New Jersey that dispersed malathion over a 20-mile area as far east as Staten Island. That accident caused approximately 100 people to seek emergency treatment in local hospitals (Withaker et al., 1984).

The tragedy of Bhopal crystallized public opinion and catalyzed the enactment of further legislation within the United States related to the chemical producing community to become more responsible to its employees and citizens living in chemical surroundings.

2. Background

2.1. USA governmental controls in place at the time of the accident

Widespread environmental consciousness in the US began in the early 1960s with publication of the book: ‘Silent Spring,’ written by ecologist Rachel Carson (Carson, 2002). The US Congress soon began debating with increased earnestness legislation to protect human health and the environment against toxic substances. Table 1 presents a time line of major events in the United States that contributed to the enhancement of environmental protection and process safety.

The primary regulatory agency for the environment in the US is the Environmental Protection Agency (EPA) established in June, 1970, through the consolidation of several agencies existing at the time (see Ref. EPA-2, 2004). Most states also had local environmental protection

<table>
<thead>
<tr>
<th>Date</th>
<th>Process safety or environment landmark</th>
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<tbody>
<tr>
<td>1 Jun 1962</td>
<td>‘Silent spring,’ by Rachel Carson appears—initiates public concern for the environment due to overuse of pesticides</td>
</tr>
<tr>
<td>22 Apr 1970</td>
<td>First ‘earth day’</td>
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<td>9 Jun 1970</td>
<td>Reorganization plans issued by President Nixon—establishing the EPA</td>
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<td>29 Dec 1970</td>
<td>Occupational safety and health act (OSHA) of 1970 enacted by the 91st congress</td>
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<td>31 Dec 1970</td>
<td>President Nixon signs into law the clean air act (CAA)</td>
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<td>11 Oct 1976</td>
<td>AIChE establishes the</td>
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<td>21 Oct 1976</td>
<td>President Ford approves the toxic substances control act (TSCA)</td>
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<tr>
<td>28 Dec 1977</td>
<td>President Carter approves the clean water act of 1977</td>
</tr>
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<td>Dec 1980</td>
<td>Congress authorizes the superfund: includes: comprehensive environmental response, compensation and liability act (CERCLA) superfund amendments and reauthorization act (SARA) emergency planning and community-right-to-know act (EPCRA)</td>
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<td>2 Dec 1984</td>
<td>Accident at Bhopal</td>
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<tr>
<td>1985</td>
<td>AIChE establishes the center for chemical process safety (CCPS)</td>
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<tr>
<td>17 Oct 1986</td>
<td>President Reagan signs the SARA reauthorization act. CERCLA was amended.</td>
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<tr>
<td>9 Oct 1987</td>
<td>EPA Administrator Lee M. Thomas signs the final rule for hazardous-chemical reporting requirements under superfund title III, Sections 311 and 312, the emergency-planning and community-right-to-know law. (EPCRA) Requires MSDS to be provided to emergency response personnel. Local emergency planning committees (LEPCs) required.</td>
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<td>1987</td>
<td>EPA conducts first ‘toxics in the community,’ toxic release inventory (TRI) survey</td>
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<td>15 Nov 1990</td>
<td>President Bush signs the clean air act amendments.</td>
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<tr>
<td>24 Feb 1992</td>
<td>Occupational safety and health administration (OSHA) process safety management standard (PSM); (29 CFR 1910.119) appears in the federal register</td>
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<tr>
<td>31 Jan 1994</td>
<td>EPA list of substances and threshold quantities for accident prevention program appears in the federal register</td>
</tr>
<tr>
<td>20 Jun 1996</td>
<td>EPA accidental release prevention requirements: risk management program (rmp) appears in the federal register</td>
</tr>
<tr>
<td>1998</td>
<td>Chemical safety board is initiated.</td>
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<tr>
<td>5 Aug 1999</td>
<td>President Clinton signs the chemical safety information, site security and fuels regulatory relief act (CSISSFRRA)</td>
</tr>
<tr>
<td>12 Jun 2002</td>
<td>Congress enacted 29 U.S.C. 669a, to expand the OSHA act to include ‘health and safety of workers who are at risk for bioterrorist threats or attacks in the workplace’</td>
</tr>
</tbody>
</table>
agencies in place, but with widely differing degrees of muscle. Their work focused mainly on water pollution problems and with the reduction of airborne nitric oxide and sulfur dioxide emissions from stationary and mobile sources.

One of the predominant pollution control issues of the time was the switch from non-catalytic emission controls for passenger vehicles to catalytic controls to reduce emissions of nitric oxide, carbon monoxide, and hydrocarbons. Stationary sources such as electric power plants also came under pressure to reduce sulfur emissions from coal by switching from high to low-sulfur coal and to #6 oil and natural gas. During that time, EPA was regulating only eight toxic pollutants and developing standards for several others of immediate priority. Methyl isocyanate (MIC) was not on that list (Long and Hansen, 1985).

Rules and regulations for the protection of plant employees were also becoming established after passage in 1970 of the Occupational Health and Safety Act (OSHA-1, 2004) which created that Occupational Safety and Health Administration. Early OSHA programs concentrated on in-plant accidents and exposures to toxic chemicals. At the time, OSHA had set permissible exposure limits (PEL) for various chemicals. MIC’s PEL was set at 0.02 ppm averaged over eight hours (Long et al., 1985), a value that was and still is one of the lowest for any chemical on the list. It was clear that MIC at that early time was seen as a highly lethal toxic chemical.

OSHA’s Hazard Communication standard, issued in November of 1983, required that companies provide information to their employees on hazards in the work place by means of labels, material safety data sheets (MSDS), and thorough training programs (Long et al., 1985). Labeling and MSDS requirements were to become effective on 25 Nov 1985.

The regulatory impact of the Bhopal disaster strongly influenced the work of EPA and OSHA and required a substantial amount of coordination and communication between the two agencies. EPA has authority for offsite consequences while OSHA’s responsibility is directed toward on-site regulation (see Ref. EPA-3, 2004). One issue, still not resolved, is whether exposure standards for workers should be any lower than EPA’s standards for the public that resides near chemical operations.

The US Department of Transportation (DOT) was also given considerable responsibility for public protection against chemical leakages from trains, trucks, and aircraft. DOT developed a signage system for placarding transportation units that transport hazardous chemicals around the United States (known as the DOT hazard identification and classification system). At the time of the accident, these placards concentrated on flammability of MIC, and did not note MIC’s hazard as a toxicant (C&E News, 24 Dec 1984, p5).

Another key law in the control of toxic chemicals was the Toxic Substances Control Act (TOSCA), signed by President Ford on 11 October 1976 (see Ref. EPA-4, 2004). This act gave the EPA the ability to track the 75,000 industrial chemicals produced or imported into the United States. EPA repeatedly screens these chemicals and can require reporting or testing of those that may pose an environmental or human-health hazard. EPA can ban the manufacture and import of those chemicals that pose an unreasonable risk.

On 21 October 1976, related legislation was enacted in the form of the Resource Conservation and Recovery Act (RCRA). That law required EPA to identify and publish a list of hazardous wastes and to set standards for the handling, transportation, and ultimate disposal of such wastes. States were to establish regulatory programs subject to EPA approval. Civil and criminal penalties were established for violation—up to $25,000 per day of noncompliance, a year in prison, or both (see Ref. EPA-5, 2004). Essentially, RCRA was the first Federal legislation to control disposal of chemicals into open dumps. Producers became responsible for the ultimate disposal of their wastes, and for transporting and disposing of them according to EPA standards. Hazardous waste transporters and treatment, storage and disposal facility operators were also subject to the new regulations (see Ref. EPA-6, 2004).

Three related acts that became lumped under Superfund legislation completed the major lawmaking in the pre- and post-Bhopal period. They were the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), and the Emergency Planning and Community Right-to-Know Act (EPCRA) (see Ref. EPA-7, 2004). At the time of the Bhopal accident only CERCLA (1980) had been enacted. CERCLA provided the funding needed to clean up hazard waste sites across the United States, 114 of which were identified by the end of 1981.

2.2. US chemical industrial efforts in loss prevention

The chemical industry has a very active group of loss prevention specialists working under the auspices of the American Institute of Chemical Engineers (AIChE), New York, NY. This group organized the first Loss Prevention Symposium in 1967 and has met annually ever since (see Ref. AIChE-1, 2004). Many of the papers are published in the AIChE Safety and Health Division journal Process Safety Progress.

2.2.1. DIERS

The Design Institute for Emergency Relief Systems, DIERS, (part of the AIChE) was formed in 1976 in response to an alarming series of reactor explosions in North American chemical plants. The explosions were occurring despite the installation of protective relief systems that were regarded as acceptable at the time. One recorded case history involved the explosion of a styrene polymerization reactor in 1966 in Montreal (Willey, 2000). The sight glass
in the relief system was unable to tolerate the pressure developed during two-phase relief. Concern had been growing in the process safety community, however, that the design of emergency relief systems needed improving

DIERS was originally conceived as a consortium of companies to develop methods for the design of emergency relief systems to reduce the frequency, severity, and consequences of pressure producing accidents. Over 200 companies that comprise the DIERS Users Group and cooperatively assimilate, implement, maintain and upgrade the DIERS methodology, supporting research, holding annual meetings, and preparing publications. Of particular interest is the prediction of two-phase flow venting and the applicability of various sizing methods for two-phase, vapor-liquid, flashing flow. DIERS has spent $1.6 million to investigate the two-phase vapor-liquid onset/disengagement dynamics and hydrodynamics of emergency relief systems (see Ref. AIChe-2, 2004).

2.3. USA public response to the Bhopal incident

The first recorded public meeting in response to the accident in Bhopal occurred one week after the tragedy, on Sunday evening, Dec 9, 1984, in Institute, West Virginia (WV). Institute was home to one of the Union Carbide’s largest chemical plants. At the time, the plant was the only US facility producing MIC. The Institute community demanded to know how susceptible they were to a tragedy on the scale of the Bhopal release. Carbide by then had started all production and shipment of MIC pending various safety checks involving the OSHA, EPA, and state health authorities (C&E News, 17 Dec 1984, p7). The meeting gave Institute residents little assurance of their safety once MIC production would be resumed.

2.4. First Congressional sub committee hearings

The first Congressional hearing on Bhopal and chemical safety was held on 12 December 1984, 9 days after the accident. It was convened by the House Education and Labor subcommittee on Health and Safety and appearing before it was OSHA Acting chief, Robert A. Rowland. The subcommittee told Rowland that the situation at Carbide’s Institute plant constituted an ‘emergency’ and they spent the day hearing about what was being done to protect US workers from MIC and other dangerous chemicals (Long et al., 1985).

On 14 December 1984, Representative Henry Waxman (D-CA) and Representative James J. Florio (D-NJ) held hearings in Charleston WV, some ten miles from Institute. Warren M. Anderson, Chairman of Union Carbide, and several other Union Carbide representatives testified. Representatives of the general public also testified including Perry Bryant, deputy director of Citizens Action, a public interest group in Charleston.

The upshot of those initial hearings was to reveal to the public that much work needed to be done to prepare for the possibility of serious accidents at chemical operations near them. Indeed, a national debate at all levels of government ensued, involving to an unprecedented degree the combination of public officials, citizen action groups, industry, and the public at large. A revolution was occurring in the toxic safety environment in the United States.

3. Methods

3.1. Federal governmental legislation influenced by the accident in Bhopal

3.1.1. EPA right-to-know and SARA

The Bhopal accident served as a reminder that things could go badly wrong wherever chemicals were processed, produced, and stored. Congress was quick to call hearings. Environmental and related legislation that was stalled in Congress began to be enacted. The first results were the Superfund Amendments and Reauthorization Act (SARA) signed by President Reagan on 17 October 1986 and the related Emergency Planning and Community Right-To-Know Act (EPCRA). Under EPCRA owners or operators of facilities were required to prepare or make available Material Safety Data Sheets (MSDS) for hazardous chemicals under the Occupational Safety and Health Administration regulations. An MSDS for each hazardous chemical on site or a list of MSDS chemicals was to be provided by 17 October 1987 to each state’s emergency response commission, to the local emergency planning committee, and to the fire department with jurisdiction over the facility. The first-year minimum requirement was for companies to report hazardous chemicals that were produced, used, or stored at levels above 10,000 pounds, or 4,540 kg. Materials designated ‘extremely hazardous substances’ because of their importance in terms of planning has a reporting threshold of 500 pounds (227 kg) or the threshold planning quantity, whichever was less. The rule also consolidated the originally proposed 23 health and physical categories into five: acute health hazards; chronic health hazards; sudden release of pressure; reactivity as a physical hazard; and flammability as a physical hazard (see Ref. EPA-8, 2004).

Essentially, SARA required plants that produced or used chemicals to make public any information that related to possible threats to the communities near them. The communities for their part were required to establish so-called Community Action Emergency Response (CAER) programs with the aim of ensuring that fire, police, and other safety services were quickly informed about the nature of any leak and that plans would be put in place for protecting the community from possible toxic discharges.

3.1.2. Toxic release inventory (TRI)

In 1987 the US Environmental Protection Agency (EPA) required companies to submit toxic release inventories
(TRI) as part of the ‘community right to know’ philosophy of the legislation. Since 1988, US Companies have reported TRI data to EPA annually, which the agency reviews and makes available to the public. The information contains releases in pounds via air, water, and land on an annual basis. Access to this information is available through a number of web sources including the American Chemistry Council’s Responsible Care © (see Ref. ACC-1, 2004).

3.1.3. Clean air act amendment of 1990

President George H.W. Bush signed the Clean Air Act (CAA) Amendments on 15 November 1990. Included in these amendments were a number of authorizations related to process safety and the environment. The CAA established regulations and programs to prevent accidental chemical releases and to minimize the consequences of such accidental releases when they occur. These regulations and programs were a direct outcome of response to the accident in Bhopal and related incidents that had occurred in the United States.

The CAA Amendments of 1990 established:

- Section 304. a chemical process safety management (PSM) standard to protect employees from hazards associated with accidental releases of highly hazardous chemicals in the workplace. It requires facilities having more than a threshold quantity of certain highly hazardous chemicals listed by OSHA to implement and document an accident prevention program.
- Section 112(r)(7). regulations and guidance to prevent and detect accidental releases and to require facilities with more than a threshold amount of a hazardous chemical to develop and implement risk management plans (RMPs), including off-site consequences of worst-case releases.
- Sections 112(r)(3), (4) and (5). a list of at least 100 substances that pose the greatest risk of causing death, injury, or serious adverse effects to human health or the environment from accidental releases, along with a threshold amount for each substance.
- Section 112(r)(6). a Chemical Safety and Hazard Investigation Board (CSB) to investigate accidental releases and advise EPA and the Department of Labor, Occupational Safety and Health Administration (OSHA) on the efficacy of their regulatory programs.

The Process Safety Management (PSM) Standard is the most comprehensive legislation directly affecting the chemical industry as a result of Bhopal. The full rule, issued on 24 February 1992, is entitled ‘Processes Safety Management of Highly Hazardous Chemicals, Explosives and Blasting.’ A complete listing of 29 CFR 1910.119 is available on the Internet (see Ref. OSHA-1, 2004). The purpose of this rule was to prevent or minimize the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. These releases may result in toxic, fire or explosion hazards. PSM rules involve any chemical at or above a specified threshold quantity (TQ) as provided in the list. MIC’s TQ is 250 lbs (114 kg). Hydrocarbons used for fuel purposes are exempted.

Several items in 29 CFR 1910.119 were self-regulated by the industry. Before PSM, companies could decide their own process safety policy within the plant and corporation with few guidelines. For example, ‘management of change’ was previously determined within a company. Policies varied tremendously from plant to plant. If a pump should fail, a local foreman could change-out a pump with another type with no formal hazard review. Under the new rules, this change out is not allowed without a hazard review of the consequences unless it is with a replacement ‘in-kind’ (the identical pump is swapped in). Previous to this rule, a number of process accidents occurred where a process change was made with very little analysis and documentation of the consequences.

3.1.3.1. EPA-RMP. Under the Clean Air Act Amendment of 1990, the EPA initiated a Risk Management Plan (RMP) with the final rule issued in June 1996 (see Ref. EPA-10). If the process is subject to an OSHA PSM, portions of the PHA conducted can serve as the initial process hazard analysis for EPA purposes. However, the EPA RMP considers only offsite impacts while the OSHA PHA considered only onsite impacts.

A well-done PHA identifies all failure scenarios that could lead to significant exposure of workers, the public, or the environment. The only issue that requires further consideration is whether protection measures that are adequate for worker safety are inadequate for public and environmental safety. For flammables, any scenario that could affect the public almost certainly would have the potential to affect workers; measures taken to protect employees likely will protect the public and the environment. For toxics under PSM, however, a loss of containment by venting toxic vapors to the outside air may not affect the employees, but may affect the public and the environment. In each circumstance, a PHA should define how the loss of containment could occur. However, for the RMP, the PHA team should reassess venting as an appropriate mitigation measure.

The RMP must analyze the worst-case ‘distance to endpoint’. It is the distance intended to provide an estimate of the maximum possible area that might be affected by a catastrophic release from a facility. It is intended to ensure that no potential risks to public health are overlooked, but the distance to an endpoint estimated under worst-case conditions need not be considered a ‘public danger zone.’ Mathematical models can be used to analyze the worst-case release scenario as defined in the rule. When estimating the worst case release distances, the rule does not allow facilities to take into account active mitigation systems and practices that could limit the scope of a release. Specific systems (e.g., monitoring, detection, control, pressure relief,
alarms, and mitigation) may limit a release or prevent the failure from occurring.

Congress mandated that RMPs be made available to the public, except for any Confidential Business Information (CBI) they may contain. Public access to the Off-Site Consequence Analysis (OCA) sections of RMPs is restricted, but the public may still read, as well as copy, these sections.

EPA originally planned to place the RMP information system on the Internet for easy access by the public, as well as by governments, based on the recommendation of many members of a Subcommittee created under the Federal Advisory Committee Act. However, concerns were raised that Internet access to a large, searchable database of OCA results could be used as a targeting tool by terrorists and other criminals. Although EPA subsequently decided not to place the OCA sections of RMPs on the Internet, new concerns were raised that recent amendments to the Freedom of Information Act (FOIA) would compel EPA to release this information in electronic format. Congress responded by passing the Chemical Safety Information, Site Security and Fuels Regulatory Relief Act (CSISSFRRA), which the President signed on August 5, 1999.

3.1.3.2. Chemical safety board. The US Chemical Safety Board (CSB) was authorized by the Clean Air Act Amendments of 1990 and became operational in January 1998. The Senate legislative history states: ‘The principal role of the chemical safety board is to investigate accidents to determine the conditions and circumstances which led up to the event and to identify the cause or causes so that similar events might be prevented’ (see Ref. CSB-1, 2004).

Congress gave the CSB a unique statutory mission and provided in law that no other agency or executive branch official may direct the activities of the Board. Following the successful model of the National Transportation Safety Board (NTSB) and the Department of Transportation (DOT), Congress directed that the CSB’s investigative function be completely independent of the rulemaking, inspection, and enforcement authorities of EPA and OSHA. Congress recognized that Board investigations would identify chemical hazards that were not addressed by those agencies (from CSB-1, 2004). Although the Board was created to function independently, it also collaborates in important ways with EPA, OSHA, and other agencies (from CSB-1, 2004).

3.1.4. NTSB-signage

After the accident in Bhopal, the National Transportation Safety Board (NTSB) urged the Department of Transportation to give priority attention to re-examining its hazard identification and classification system. At the time, MIC’s primary hazard classification by the DOT was based on its flammability. The board concluded: ‘many questions now unanswered by DOT’s hazard identification and classification system must be answered to determine which flammable liquids, Class B poisons, corrosives, and other materials can pose life threatening hazards during accident conditions as we now know MIC can’ (C&E News, Dec 24, 1984, p5). An outcome from this is that all transportation vehicles must have NTSB diamonds clearly shown on their vehicles. These diamonds now have differing backgrounds depending upon the severest consequence (toxicity, reactivity, or flammability) that the material processes.

3.2. Industrial sector responses

Industrial responses evolved collectively through various trade associations. The most notable is the Responsible Care® program initially started under the Chemical Manufacturers Association (CMA) which later became the US American Chemistry Council (ACC). The following information is modified from the ACC website (see Ref. ACC-2, 2004).

‘Since 1988, members of the American Chemistry Council (ACC) have significantly improved their environmental, health, safety and, in recent years, security performance through the Responsible Care initiative. Participation in Responsible Care is mandatory for ACC member companies, all of which have made CEO-level commitments to uphold these requirements:’

- Measuring and publicly reporting performance;
- Implementing the Responsible Care Security Code;
- Applying a modern management system to achieve and verify results; and
- Obtaining independent certification that a management system is in place and functions according to professional standards.

‘Responsible Care companies use a modern management system to drive environmental, health, safety and security performance. This approach provides a rigorous and structured framework for assessing a company’s needs, setting specific goals and sharing progress and activities with the public. A key component of the management system is mandatory certification by independent, accredited auditing firms.’

The Responsible Care web site (see Ref. ACC-3, 2004) offers links to performance data (by company and by the aggregate) in the areas of the environment (the TRI discussed above), process safety (recordable incident rate presented below), security, products, accountability, and economy (research and development expenditures).

Additional initiatives came from other industrial trade organizations such as the Chlorine Institute (see Ref. CI-1, 2004), the American Petroleum Institute (API) which initially drafted what was to become the OSHA PSM (see Ref. OSHA-2, 2004), and National Association of Chemical Distributors (NACD) who initiated Responsible Distribution (see Ref. NACD-1, 2004).

Many US corporations place extensive emphasis on process safety as can be witnessed in corporate annual
3.3. Professional societies changes influenced by the accident in Bhopal

The AIChE took the main lead to initiate stronger commitments to process safety for the private sector. Founded in 1985, The Center for Chemical Process Safety (CCPS) brings together manufacturers, insurers, government, academia, and expert consultants to lead the way in improving manufacturing process safety.

CCPS and its sponsors are committed to protecting employees, communities, and the environment by developing engineering and management practices to prevent or mitigate catastrophic releases of chemicals, hydrocarbons, and other hazardous materials. The Center’s charter has the following goals (see Ref. AIChE-3, 2004):

- ADVANCING state-of-the-art process safety technology and management practices.
- SERVING as a premier resource for information on process safety.
- FOSTERING process safety in engineering and science education.
- PROMOTING process safety as a key industry value.

Since 1985, CCPS has published over 80 books and products, held 18 international conferences, and cultivated our Safety in Chemical Engineering Education (SACHE) university curriculum program (discussed in detail below). CCPS published 12 elements of process safety to help companies identify the key tenets of a process safety program. These 12 elements of process safety are listed available on the Internet (see Ref. AIChE-4, 2004). The CCPS recipe for success is collaboration focused on a need. Participants from sponsor companies identify needs, pool their knowledge, and leverage their resources to consolidate industry best practices toward meeting those needs. In the process, they learn from each other and from the world’s experts, benchmark their companies programs, and raise the image of the industry as a whole (text adapted AIChE-4, 2004).

3.4. Academic response influenced by the accident in Bhopal

The following is adapted from Ref. AIChE-5, 2004. After its founding in 1985, one of the first projects of the AIChE Safety and Health Division was to incorporate loss prevention into 6 or 7 major chemical engineering courses taught at the university level. The division asked Tom Carmody, the founding director of the AIChE Center for Chemical Process Safety (CCPS), if a set of problems demonstrating process safety for the core courses could be part of CCPS’s work. He agreed that it would be a good project, but was not sure CCPS could fund it completely. About that time it was learned that there might be some National Science Foundation money available for work. CCPS applied for and received a grant. That was the initiation of the AIChE CCPS Undergraduate Education Committee (UEC). Owen Kubias, then S and H division chair, became chair of the committee.

The committee drew up a set of criteria for the project and solicited bids from interested universities. The proposal by Reed Welker and Charles Springer from the University of Arkansas was accepted. Two books resulted from this effort. The first book was directed at the students and contained the problem statements and background material on the importance of the problem. The second book was a solution manual for faculty that also included additional supporting materials. The books were published in 1990 and became best sellers for CCPS.

A meeting of the CCPS Undergraduate Education Committee at the AIChE Annual Meeting in Chicago in 1990 was pivotal for the next educational activity of CCPS. It was clear that a more proactive method was required to excite universities about process safety. Joe Louvar, Dan Crowl, and Owen Kubias presented papers at the 1990 Annual Meeting in Chicago on the integration of process safety into the chemical engineering curriculum. While waiting for a late afternoon presentation, Louvar, Crowl, and Kubias conceived the acronym SACHE - Safety and Chemical Engineering Education. The Undergraduate Education Committee also discussed ways to continue the committee’s activities and arrived at the idea of offering teaching materials demonstrating process safety to universities each year for a nominal membership fee. The idea behind SACHE is simple: provide a consortium of member universities that join together to prepare and distribute instructional materials in process safety at minimal cost.

At the Annual Meeting in Los Angeles in 1991, this new program was presented to a meeting of chemical engineering professors. Over 30 schools made an immediate commitment to the SACHE program. Since then, some 125 universities have joined SACHE from within the US and around the world.

The initial focus of SACHE was to prepare teaching modules for use in the chemical engineering classroom. These modules are prepared by industrial and academic contributors under contract from SACHE. The modules are reviewed by the SACHE committee. The purpose of the modules is to provide instructional resource materials for faculty. To date, over 40 modules have been prepared and distributed. Earlier modules included slide, lecture and background materials, but more recent modules have replaced the slides with PowerPoint based materials. A listing
of these instructional modules is available on the Internet (see Ref. AIChE-6).

SACHE has also hosted seven faculty workshops on process safety (four at BASF in Wyandotte, MI, two at Dow Chemical in Freeport, TX, and one at Exxon-Mobil in Baton Rouge, LA). These workshops consisted of lectures on the fundamentals of process safety, followed by plant and laboratory tours and demonstrations to show how the fundamentals are put into practical application. The faculty are also given a good dose of industrial safety culture, with the hope that this will translate into faculty efforts to meet undergraduate student needs in process safety.

Currently, SACHE is implementing web-based instructional materials that students would use directly.

4. Results

Figs. 1–3 were taken from the US Census Statistical Abstracts (US Department of Commerce, 2003). Each one shows declining trends, meaning fewer fatalities in all of manufacturing (Fig. 1), fewer deaths in all of manufacturing per 100,000 (Fig. 2), and fewer OSHA reportable incidents (Fig. 3). Each figure shows a time lag of about 8 years, but the drops are significant. US Industry is now safer.

As reported directly by EPA (see Ref. EPA-9, 2004), ‘Chemical accidents continue to impose considerable costs in terms of human lives and health, property damage, and public welfare. Facilities covered by the RMP rule reported that from mid-1994 to mid-1999 there were about 1,900 serious accidents that caused 33 deaths, 8,300 injuries, and the evacuation or sheltering of 221,000 people. These accidents cost the affected facilities more than $1 billion in direct damages and two to four times that in business interruption losses. Almost 80% of these accidents occurred at facilities already subject to the OSHA process safety management standard, which is designed to reduce

4.1. Success of the TRI

Fig. 4 shows a continue drop in toxic releases as time continues. The following is taken directly from an EPA report (see Ref. EPA-9, 2004).

‘Given the opportunity, the public uses hazard information to take action that leads to risk reduction. Various segments of the public have strong incentives to use OCA information in ways that reduce risk. For example, there is a broad consensus that national publication of the Toxics Release Inventory (TRI) data by the government, followed by analysis by citizens groups and the news media, led to action by industry to reduce emissions. Nationally, reported TRI emissions have fallen 43 percent since 1988, a time in which industrial production has risen 28 percent. Although other factors likely contributed to the decline in emissions, negative press coverage directed at certain facilities appears
to have led these facilities to achieve reductions in their TRI emissions."

The report goes on to point out the importance of public access to the information.

"Ease of access to information is important to public use and risk reduction. Data available in paper form on request from state or local agencies are rarely sought. For example, data on the location and identity of hazardous chemicals are requested about 3,500 times a year from Local Emergency Planning Committees (LEPCs). There are about 3,200 LEPCs in the country and about 560,000 facilities subject to requirements to report information on hazardous chemicals to LEPCs. Meanwhile, environmental data on Environmental Defense’s ‘Scorecard’ website are at least 250 times more likely to be reviewed by the public than information from LEPCs. Likewise, early indications are that the meetings which facilities were required to conduct by CSISSFRRA to explain OCA information to the public have drawn very few attendees, even when citizens received individual invitations. In contrast, when industry has gone out to places the public already frequents (for example, a shopping mall) and provided consequence information directly to citizens, outreach and communication about chemical accident risks has been more successful."

4.2. Academia

Recognition of the importance of process safety to the education of students is demonstrated by a change in Accreditation Board for Engineering and Technology, Inc. (ABET, 2005) criterion for chemical engineering programs in 2000. The criterion was changed by the addition of wording related to safety and the environment in the ABET 2000 criteria (initiated in 2001). The criterion for chemical engineering programs in the United States now reads (see Ref. ABET, 2005):

‘The program must demonstrate that graduates have: thorough grounding in chemistry and a working knowledge of advanced chemistry such as organic, inorganic, physical, analytical, materials chemistry, or biochemistry, selected as appropriate to the goals of the program; and working knowledge, including safety and environmental aspects, of material and energy balances applied to chemical processes; thermodynamics of physical and chemical equilibria; heat, mass, and momentum transfer; chemical reaction engineering; continuous and stage-wise separation operations; process dynamics and control; process design; and appropriate modern experimental and computing techniques.’

The ambitious CCPS sponsored SACHE program has resulted in two major results. First, over 40 modules have been prepared and distributed to chemical engineering departments for faculty use in instruction of process safety. Second over 150 professors from more than 130 universities have completed the SACHE workshop and have brought their knowledge back to their home universities. Approximately 50 US universities now offer process safety courses. Approximately 10 of these universities have required courses. Many integrate process safety into existing courses, including design, UO lab, and others. Content has also appeared in textbooks for other courses (Fogler, 1992).

5. Conclusions

The accident in Bhopal had a profound effect within the United States. It resulted in a substantial change in US regulations, the formation of the AICHE Center for Chemical Process Safety, and the formation of the Safety and Chemical Engineering (SACHE) program. These initiatives resulted in a change in the practice and education of chemical engineers in the US.

Certainly lives have been saved. Furthermore, practicing and graduating chemical engineers are much more aware of process safety and environmental issues through professional and educational development.

References
