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CHEMICAL AND NUCLEAR EMERGENCIES: INTERCHANGING LESSONS LEARNED FROM PLANNING AND ACCIDENT EXPERIENCE

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ABSTRACT

Because the goal of emergency preparedness for both chemical and nuclear hazards is to reduce human exposure to hazardous materials, this paper examines the interchange of lessons learned from emergency planning and accident experience in both industries. While the concerns are slightly different, sufficient similarity is found for each to draw implications from the other's experience. Principally the chemical industry can learn from the extensive planning and exercise experience associated with nuclear power plants, while the nuclear industry can chiefly learn from the chemical industry's accident experience.

LES SITUATIONS D'URGENCE CHIMIQUE ET NUCLEAIRE : ECHANGE D'ENSEIGNEMENTS TIRES DE L'EXPERIENCE EN MATIERE DE PLANIFICATION ET D'ACCIDENTS

RESUME

Etant donné que les plans d'intervention en cas de risque aussi bien chimique que nucléaire ont pour but de réduire l'exposition humaine à des matières dangereuses, la présente communication traite de l'échange d'enseignements tirés de l'expérience en matière de planification d'urgence et d'accidents qui a été acquise dans l'industrie chimique et dans l'industrie nucléaire. Bien que les préoccupations soient légèrement différentes, il y a suffisamment de similitudes pour que chacune de ces industries s'inspire de l'expérience acquise par l'autre. C'est ainsi notamment que l'industrie chimique peut mettre à profit la vaste expérience en matière de planification et d'exercices associée aux centrales nucléaires et que l'industrie nucléaire peut principalement tirer parti de l'expérience de l'industrie chimique en matière d'accidents.

INTRODUCTION

The major thesis of this paper advances the notion that the sharing of knowledge will improve planning and preparedness for chemical and nuclear hazards beyond what can be achieved by merely drawing upon experience independent of one another. The general goals of emergency preparedness for chemical and nuclear accidents are the same: to reduce human exposure to hazardous materials and provide prompt care to any casualties in the event of accidental releases. In case of a release of radiation, the goal is to reduce doses that may contribute to latent cancers. In case of a release of chemicals, the goal is to reduce both exposure to peak concentration and total dose to prevent acute lethality and chronic health effects. Despite the different reasons for reducing or preventing exposure, key similarities exist. Both forms of preparedness are based upon the simple reality that dose cannot be prevented or reduced in accidents without prior coordinated planning and preparedness. In both cases, the inhalation pathway is of primary concern with secondary concern with deposition and ingestion pathways. The major means of population protection are the same and include evacuation, sheltering, and respiratory protection. Both nuclear and chemical accidents can develop quickly, threatening the nearby population with little or no prior warning. Finally, although the details of response efforts differ, the overall form of response is the same, particularly in the early phase of an emergency.

Given these similarities, there is a compelling wisdom in sharing knowledge derived from planning and accident experience associated with chemical and radiological hazards. The transfer need not and should not be one way. The experience of the radiological programs in the U.S. can provide valuable input into chemical programs as well.

The next section of the paper examines the U.S. experience with chemical accidents during the 1980's. Developments in emergency planning for chemical hazards in terms of national policy and community implementation of that policy are then reviewed. The next section illustrates how planning and accident experiences can be shared to improve preparedness for both chemical and nuclear incidents. Finally, some promising directions for future knowledge transfer are addressed.

THE U.S. EXPERIENCE WITH CHEMICAL ACCIDENTS

In the decade of the 1980's, there have been, at a minimum, almost 800 evacuations in the U.S. prompted by the release or threat of a release of hazardous materials. Figure 1 shows the incidence of reported evacuations by type. On average, 90 evacuations are reported each year. The number increased markedly in 1985. This reflects, we suspect, the influence of the Bhopal accident on reporting as well as decision making. Evacuations were likely to receive greater publicity after that event. In addition, there is reason to suspect that public officials have been more willing to recommend or order an evacuation in order to err on the side of caution.

During the period from 1980 through 1984 non-occupational exposure to chemicals, which led to reported injury, occurred in one out of every four incidents [1]. On average 28 people were injured due to exposure in those evacuations in which exposures occurred. During that same period only one suspected non-occupational fatality occurred. The experience world-wide and during other time periods in the U.S. shows a different picture. The most serious accident in U.S. history was caused by a ship explosion (ammonium nitrate) in Texas City in 1947, which killed 552 people. Most recently, a natural gas explosion in the USSR killed a reported 400 people. Estimates of the fatalities at Bhopal range between 2500 and 10,000 [2,3] with an additional 200,000 injuries [4].

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Given this record, two points germane to the thesis of this paper are clear. First, the U.S. has had much more experience with chemical accidents than with nuclear. The Three Mile Island accident (TMI) remains the only nuclear incident that has led to off-site response. Chernobyl did not disrupt the lives of residents of the U.S. as it did in Europe. In the U.S., readiness for a nuclear accident comes through exercises. These exercises, however, cannot fully duplicate the lessons learned from real emergency situations. The nuclear industry can therefore learn from the real world of chemical incidents. The second clear lesson is that the likelihood of injury or imminent death is far greater in chemical accidents. Even at Chernobyl, no acute fatalities occurred among the general public.

STATUS OF EMERGENCY PLANNING FOR CHEMICAL ACCIDENTS

Unfortunately our ability to learn lessons from responses to chemical accidents is constrained by the fact that overall preparedness levels, for chemical emergencies is low for most U.S. communities. Frequently, response to such emergencies is done in an ad hoc manner due to the fact that most U.S. communities ignored the danger of chemicals until the accident at Bhopal. The accident at the Union Carbide Plant in Bhopal, India on December 3, 1984, was caused by a release of methyl isocyanate (MIC). This initiated concern in the U.S. that catastrophic chemical accidents could also occur in U.S. facilities. This was partially confirmed when, on August 11, 1985, a release of chemicals during the production of aldicarb from Union Carbide's Institute, West Virginia facility sent 130 people to the hospital [5]. Later investigations revealed many violations of safety procedures and poor management practices. In 1986, Congress passed the Superfund Amendments and Reauthorization Act (SARA). Title III of that Act, titled "Emergency Planning and Community Right to Know," mandated the requirements for emergency planning for chemical accidents. Among the key features of Title III are:

- establishment of State Emergency Response Commissions (SERC) which establish within each state a set of emergency planning districts and appoints a Local Emergency Planning Committee (LEPC),
- the LEPC must prepare a comprehensive emergency plan,
- this plan must be reviewed at least yearly or when changes occur in the community or covered facilities,
- the LEPC must evaluate its need for resources necessary to develop, implement, and exercise the plan,
- plans must be submitted to the SERC for review, and
- a set of planning elements is specified in the law.

In 1988, a survey was conducted to ascertain the status of emergency preparedness for chemical hazards in U.S. communities [6,7]. The survey was replicated with a random sample of 400 communities in the Federal Emergency Management Agency's (FEMA) data base on community emergency plans that indicated that they had at least one fixed-site hazardous material facility in the community. Responses were received from slightly over 50% of the communities. These data provide us with the means of assessing the status of planning and preparedness for chemical hazards. Survey results regarding various practices are shown in Figure 2.

Almost all communities surveyed (98%) had a community emergency plan. Slightly over three-quarters of the communities addressed chemical hazards in their plan. Only 55% had annexes specific to individual facilities. Fewer communities have developed emergency operating procedures for chemical accidents. Only 28% had developed a procedure to make a protective action decision while slightly more had a procedure for making a decision to issue a public warning. About half of the communities had attempted to provide some form of public education on chemical emergency response.

In contrast, all communities potentially affected by a release at a nuclear power plant are required to have plans that address the nuclear hazards associated with the specific plant in order to obtain an operating licence. Furthermore, these communities, often with the help of the nuclear industry, have installed emergency warning systems that are required to alert people within specified emergency planning zones concerning the potential hazards and notify them regarding appropriate protective actions within specified time limits.

The implications of these example findings are clear. Chemical emergency planning lags far behind radiological planning in a number of ways including exercises, plans, procedures, and response capabilities. Communities surrounding chemical facilities are simply less prepared to deal with emergencies. One way that communities can learn from the nuclear industry is in the vast and more rigorous planning experiences generated by the radiological emergency preparedness (REP) program.

Despite the fact that chemical accidents that lead to public protection occur far more frequently than nuclear accidents, that more people have been killed worldwide and in the U.S. by chemical accidents than nuclear, and far more people are exposed to chemical releases than nuclear releases, the requirements for emergency planning for chemical accidents are far less stringent requirements than for nuclear power plants. The consequences of this disparity are underscored by the recent Valdez oil spill in Alaska which overwhelmed planning and response capabilities [8].

INSTITUTE, WEST VIRGINIA AND NANTICOKE, PENNSYLVANIA: CONTRASTING EXPERIENCES

The benefits of the REP program for chemical emergency planning are illustrated by the differences in the Institute accident in 1985 and the March, 1987, accident at Nanticoke, Pennsylvania. The Institute, West Virginia accident occurred when a release of unknown chemicals occurred while producing aldicarb which is manufactured from aldicarb oxime, methylene chloride and MIC [9]. Later analysis identified some 26 chemicals that were released. The accident occurred at 9:25 a.m on Sunday morning. The cloud, described as being yellowish in color drifted over the communities of Institute, Dunbar, and West Dunbar with a total population of about 11,500 people. Immediately after the release, warning sirens were sounded and radio and television announcements were made. The public was told not to evacuate. No evacuation routes had been established nor did a community emergency plan exist [2]. A total of 130 people were treated for injuries.

Following the accident, two surveys were conducted: one with a random sample of 406 households in the three communities [9]; the other with 130 victims. Only 5% of both samples reported being warned by the sirens. Among the victims, 45% learned of the release by smelling the fumes, three times the rate for the random sample.

The experience of the community of Nanticoke, Pennsylvania, which was in a more advanced state of preparedness, stands in sharp contrast to the experience in West Virginia. The Nanticoke accident took place on March 24, 1987. A few minutes before 12:30 a.m., an electrical fire at a metal processing plant generated a toxic cloud of unknown materials or toxicity [10]. The fire

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In the Nanticoke accident, a hazardous material evacuation plan had been developed to guide response. It was based on the same approach that had been used to develop a plan for a nearby nuclear facility that served as the model for an all-hazards planning approach in the community [11]. While some minor problems occurred, post accident assessments generally agreed that the response was successful and evacuation went very well, mainly due to the prior planning using the REP framework [11,12]. While most residents heard the sirens, there was initial ambiguity over the meaning of the sirens with many residents believing there had been a nuclear accident. Tests by the nuclear power plant indicate that 77% of the population in the emergency planning zone (EPZ) reported hearing a test of the sirens. This is in sharp contrast to the 5% who were warned by sirens at Institute. Overall, the incident indicates the impact that the REP program has had on emergency preparedness. When the 1983 Taft, Louisiana evacuation occurred in the EPZ of the Waterford Power Plant, the REP plan had not been integrated with hazardous material planning [13], even though the planning process helped in achieving an effective evacuation [14].

LEARNING FROM CHEMICAL ACCIDENTS: EVACUATION EXPERIENCES

A study was conducted in 1987 at Pennsylvania State University to measure the risk of injuries and fatalities during emergency evacuations [15]. Data were collected from surveys sent to local emergency managers concerning 310 evacuations in the U.S. The purpose of the study was to estimate the risks of injury and fatality in an evacuation. While many of the central conclusions of the study are questionable, the data collected can be used to address other interesting emergency planning issues. Figure 3 shows data on the estimated size of the evacuation as measured by number of evacuees and the estimated clearance times as measured by the time it took to complete the evacuation to a safe location. This enables us to assess if it takes longer to move a greater number of people. The results, which are based on 66 chemical accidents with warning times of less than 10 hours and for which data are available, indicate that there is no significant relationship between the two variables. The prevailing logic among emergency planners is that it takes more time to move a greater number of people; this is not corroborated by these data.

Two factors seem to intervene. First, the time it takes to evacuate is partly determined by the urgency of the situation. If there is the need to move quickly people respond accordingly. If the situation is not immediately threatening, people take more time. Second, as population increases, the infrastructure to move a greater number of people also increases. To test this latter proposition, the size of the evacuation is compared with the evacuation rate as measured by the number evacuating per hour. As the number evacuating increases, the rate also increases. This supports the notion that some infrastructures help move larger populations in time frames similar to smaller populations. This does not mean that significant traffic congestion does not or cannot occur in evacuations.

These results underscore the value of data on emergency evacuations. The current evacuation plans for nuclear power plants exist primarily on paper and are based on modelled evacuation time estimates and not on actual experience.

LEARNING FROM CHEMICAL ACCIDENTS: WARNING EXPERIENCES

On Saturday, April 11, 1987 at 12:29 p.m., a westbound Conrail freight train derailed in Pittsburgh, Pennsylvania. In the process of derailing, the westbound train sideswiped an eastbound train causing it to derail. Four tank cars containing hazardous materials on the eastbound train were derailed. Sparks resulting from the accident ignited a fire; however, none of the hazardous materials ignited. Pittsburgh emergency personnel initiated an evacuation upon arrival at the scene, about 20 minutes after the accident. Some local residents in immediately adjacent areas had already begun to evacuate. Up to 22,000 people were evacuated as the initial evacuation area was expanded to accommodate changing weather conditions. The fire was extinguished by 3:30 p.m., however, the primary concern centered around a derailed tank car containing phosphorus oxychloride. This tank car developed a crack in the dome permitting between 30 and 100 gallons of lading to escape. By 5:50 p.m., the affected areas had been declared safe and the initial evacuation order was rescinded. A close inspection of the damaged tank car shortly after midnight detected continued degradation of the tank car. At 1:30 a.m. a second evacuation order affecting between 14,000 and 16,000 residents within a half mile of the scene was issued. This second evacuation order was not rescinded until 4:30 p.m. on Sunday, April 12, 1987. Approximately 25 people were treated for eye and throat irritation at area hospitals, and three people were hospitalized during the course of the accident.

On Wednesday, May 6, 1987 at 4:10 a.m., 21 of 27 "empty" tank cars carrying product residues, including propane, chlorine, caustic soda, carbon disulfide, methyl chloride, chloroform, and isobutane derailed in Confluence, Pennsylvania. Because tank cars carrying residue can haul up to 3% of the load, emergency officials had no way to determine the exact amount of products remaining in the cars. Emergency management officials initiated a precautionary evacuation of the 986 residents. A three-minute non-stop siren blast was sounded, which primarily alerted the volunteer firemen. At approximately 4:30 a.m., a door-to-door and portable loudspeaker alert and notification of the emergency began using volunteer firemen and untrained volunteers, and within 45 minutes the evacuation was complete. Assistance from area-wide emergency personnel sealed two leaking propane tankers by 9:48 a.m., but the chance of explosion and/or fire during wreckage cleanup prevented return until 6:10 p.m.

Data collected by mail and telephone surveys regarding the timing of warning receipt following the train derailments in Pittsburgh, Pennsylvania and Confluence, Pennsylvania are summarized in Figure 4 as the cumulative proportion warned by time of receipt in terms of minutes into the event [16]. These are the only known data that have been collected on the timing of warning receipt following a technological accident. The measurement difficulties are clearly evidenced by the proportion of respondents that reported receiving warning prior to its occurrence.

Both warning situations are characterized as primarily consisting of route-alerting and door-to-door warning systems. Each is characterized by an S-shaped curve, with the Confluence

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WARNING EXPERIENCES

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warning reportedly approaching 90% warned in about two hours, and the Pittsburgh event reportedly approaching 80% warned in about three hours. However, because of methodological uncertainties, it is only possible to identify people who positively report having received some kind of warning it is not possible to identify those not receiving warning. While the warning situation in both Confluence and Pittsburgh are characterized by rapid dissemination in the first hour and half of the event, only 12.5% report being warned in the first 15 minutes in Pittsburgh while 36.8% reported being warned in the same period in Confluence. In Confluence, nearly 70% report receiving warning in the first hour, while only 23% report having received warning in the same period in Pittsburgh. Neither event is characterized by complete (100%) warning, and both indicate that very rapid onset emergencies can result in people being engulfed in danger prior to receiving warning.

The implications of the findings are clear: ad hoc emergency response will not prevent exposure in events with short lead times. Without good planning and advanced warning technologies, protective actions cannot be quickly implemented. This reinforces the need for the REP warning requirements (15-minute 100% notification within 5 miles) given the possibility, though small, of radiological accidents with little or no forewarning.

AREAS FOR FURTHER INTERCHANGE

This paper briefly explores the interchange of information that can benefit both the radiological and chemical emergency planning programs in the U.S. We are clearly seeing some positive benefits from shared experiences and knowledge. This is also manifesting itself in other ways at FEMA.

For example, FEMA is developing a program to improve preparedness for accidents at chemical weapons storage facilities in the continental U.S. In developing that program, many of the lessons learned from the REP program are being incorporated. For example, the program planning checklist and program standards are being modelled after NUREG 0654/FEMA REP 1 [17], a joint agency guide for developing radiological response plans.

FEMA is also preparing technical guidance on public alert and notification systems for chemical emergencies. Much of the background in the report on alert and notification technology is based on experience with developing FEMA REP 10 [18], the guidebook on warning systems for radiological planning. In addition, valuable data derived from FEMA's efforts to certify the alert/notification criteria in NUREG 0654/FEMA REP 1 are being incorporated. The REP program has pushed warning system technology into the modern age and such benefits can be shared in integrated planning.

Other areas which create opportunities for the REP program to build on chemical experiences are being pursued. For example, FEMA has just initiated a study that will investigate public response to shelter advisement in a chemical emergency. One fairly large planning uncertainty is whether the public will comply with an order to "stay put and button-up." In addition, FEMA has funded a study of evacuation experiences of institutional populations in chemical emergencies [19]. Furthermore, studies of human response to siren-based warning systems in chemical accidents may help validate results of FEMA surveys on public notification following siren tests.

As improved emergency preparedness systems are developed and implemented, it also should not be forgotten that the nuclear industry can learn from the response of the chemical industry in the U.S. to the Bhopal accident. First, the industry, through the Chemical Manufacturers

Association, initiated a program of enhanced chemical preparedness [20]. The Community Awareness and Emergency Response (CAER) program relies on industry initiative in working with local governments. The program seems to have been implemented seriously by major chemical manufacturers, although not by more marginal firms. Second, major firms initiated steps to reduce the potential source terms by reducing chemical inventories or by changing production methods. At one point, both the chemical and nuclear industries believed bigger was better. The economies of scale, however, failed to fully capture the costs of catastrophic accidents. This was recently reflected in the oil spill from the massive Valdez tanker. In the long run, such economies must be recalculated in order to achieve improved public acceptance of these technologies.

This poses a subtle irony; due to regulatory response to accidents, the status of emergency planning is most secure for nuclear plants. Due to recent efforts such as Title III, CAER, and source term reduction, larger chemical facilities are much safer than a decade ago. Large facilities are more likely to have adopted planning and safety practices because they can afford to, they are more visible in the community, and they are concerned with liability. Small marginal facilities still pose significant risks to public safety. These small marginal facilities present an emergency management problem that is far greater than dealing only with large chemical facilities, because they are less likely to have adopted enhanced emergency plans and safety practices.

This paper explored some of the synergism gained by the transfer of knowledge in planning for different technological hazards. It is quite evident that such a transfer can occur and should be encouraged. The vast experience gained from chemical accident experience and the planning and exercise knowledge gained from the REP program make the transfer viable.

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inventories or by changing production methods.
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sts of catastrophic accidents. This was recently
: tanker. In the long run, such economies must
lic acceptance of these technologies.
y response to accidents, the status of emergency
to recent efforts such as Title III, CAER, and
e much safer than a decade ago. Large facilities
ety practices because they can afford to, they are
erned with liability. Small marginal facilities still
small marginal facilities present an emergency
ling only with large chemical facilities, because
ergency plans and safety practices.
gained by the transfer of knowledge in planning
ident that such a transfer can occur and should
chemical accident experience and the planning
gram make the transfer viable.

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