RAPID ASSESSMENT OF CHEMICAL SPILLS FOR INTERNATIONAL COMMUNITIES

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DEDICATION

For my parents.

RAPID ASSESSMENT OF CHEMICAL SPILLS FOR INTERNATIONAL COMMUNITIES

By

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THESIS

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ABSTRACT

A PC based expert systems approach is developed for managing and minimizing the consequences of on-site (within a facility premise) and off-site (outside a facility premise) chemical spills in the U.S.-Mexico border region. The approach establishes user-friendly application interface consisting of four modules: 1) a 188 chemical database populated with physical/chemical properties as well as health threshold quantities, 2) an emission module for estimating chemical emission rates under various release conditions, and 3) an air dispersion module for assessing off-site impacts and defining impact zones with the aid of 4) a Geographic Information System (GIS) of the El Paso/ Juarez metroplex for graphical presentation of the modeling results to aid in emergency response.

The objective of this research is to provide the border communities and Native American reservations with a tool for assessing and dealing with the consequences of potential on-site or off-site accidents involving hazardous materials. By inputting certain parameters of the spill, the user, along with the use of real-time meteorological data and other relevant environmental data, can simulate, evaluate, and dispatch emergency responders to deal with the consequences of any hypothetical or actual chemical spill accident. The approach is designed to reduce emergency response time for both technical and non-technical users including local emergency response teams, local emergency planning committees, state air offices, local fire departments, emergency management agencies, environmental protection and public health departments, land use planning offices, and natural resource planning and management offices.

EPA guideline emission and air dispersion models are modified for application to extreme meteorological conditions, such as calm and inversion conditions, which are common in the border region. The graphical presentation allows the users to visualize the plume impacts on a GIS-based platform with levels of impact zones defined by the respective reference concentrations such as IDLH and ERPG defined concentrations. The GIS also provides the user a tool with which to contact and evacuate schools, households, medical facilities, businesses, and any other possible people in danger. Provided with the appropriate base information, the expert system approach to managing and minimizing the consequences of accidental chemical spills may be applied anywhere.

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INTRODUCTION

1.1 Accidental Chemical Spills

The handling of an accidental chemical spill is an extremely difficult task with the possibility of having many lives at stake. The pressures on the emergency response personnel to identify and respond to a chemical emergency can be extreme. Initial or emergency response to a chemical spill incident is defined as the stabilization or control required in the early stages of a release to halt further impact of the released substance on the public and the environment[1]. The emergency response to an accidental chemical spill requires the proper decision making process in order to minimize detrimental effects on the surrounding areas. Decision makers from the Federal level to the private sector, managers and employees must have at their disposal a way of expediting and predicting the process of protection and evacuation of the people at risk of exposure due to an accidental chemical spill and the many possible complications therein. Both planning and real-time response to such an occurrence are essential in accomplishing the minimization of the damage to people and property.

The motivations for the decision makers may vary, but safety is always in their best interest. They (industry decision makers) are so persuaded by the potential for criminal citation, the possible imposition of jail sentences on executives and great financial liability (economic loss due to boycotts as well), which exists with a major chemical accident[2]. Regulatory decision makers tend to be much more politically driven than their industrial counterparts.

There are hundreds of standards, codes, and guidelines for the chemical industry, which, along with the mandates of the legislation of the U.S. government, put into place a structure of safety with which to work. It is suggested that the Federal government regulate the chemical industry the way that the Nuclear Regulatory Commission regulates the nuclear industry. The executives of the chemical industry would naturally rather take matters into their own hands. This leads to the voluntary adherence to the regulations set down by the legislation and the development of new technologies to plan for and respond to accidental chemical spills. The time it takes for the emergency responders to get the situation under control becomes more critical as the toxicity of the chemical involved increases. The need for the prediction of the transport of any atmospheric releases is paramount. Thus, a professional's knowledge is required to assess and define an impact area in which evacuation is appropriate.

1.2 An Expert Systems Approach

One approach to the expedition of the emergency response process is what is known as an expert systems approach, which involves the procedural manipulation of data. The personnel involved with emergency response may not always be trained to deal with various chemicals and the reactions that may occur in a chemical accident. Expert systems attempt to simulate the knowledge and skill of a professional and his/her logic with problem solving by using artificial intelligence and if/then statements. The mechanism involved in the logical path determined by an expert system is called an inference engine. Expert systems solve problems involving interpretation, prediction, diagnosis, debugging, design, planning, monitoring, repair, instruction, and control[3].

Expert systems have been used in the chemical industry for use in instrumental diagnosis, data interpretation, and synthesis planning.

Expert systems such as ERexpert[4] and the Palmtop Emergency Action for Chemicals (PEAC) developed by the Western Research Institute[5] attempt to acquire relevant information about the spill (chemical, meteorological, and transformational information), process the data, and present the outcomes in a usable format. The complexity and randomness of the atmosphere can make it difficult for models such as ERexpert to respond to certain conditions. These expert systems can greatly expedite the determination of the impact area, yet the process of evacuation could be greatly accelerated with the use of technologies such as a geographic information system (GIS). Through the integration of an expert systems approach to the atmospheric modeling of an accidental chemical spill and the graphical display of the results on a GIS, the process of emergency response can be optimized. The GIS would allow for the immediate contact of people in the defined effected area by emergency responders and the allocation and expedition of resources by decision makers, thus saving the precious time needed to save lives.

1.3 Research Objective

In light of the need for the knowledge on the consequences of a potential chemical spill for emergency response personnel as well as the decision makers, an expert systems approach that provides a generic consequence analysis appears to be extremely desirable. The objective of this thesis, therefore, is to provide the border communities and Native American reservations with a tool for assessing and dealing with the consequences of

potential on-site or off-site accidents involving hazardous materials. That tool is named the Rapid Assessment of Chemical Emergencies (RACE) system. By inputting certain parameters of the spill, the user, along with the use of real-time meteorological data and other relevant environmental data, can simulate, evaluate, and dispatch help for the consequences of any hypothetical or actual chemical spill accident. The approach is designed to alleviate emergency response time for both technical and non-technical users including local emergency response teams, local emergency planning committees, state air offices, local fire departments, emergency management agencies, environmental protection and public health departments, land use planning offices, and natural resource planning and management offices.

1.4 Thesis Structure

The research objective and the importance of the handling of a chemical spill incident and associated concerns are discussed in Chapter 1 of this thesis. Background knowledge of the legislation on emergency response and available technical approaches to modeling the consequences of a spill incident is given in Chapter 2. Chapter 3 describes the RACE system and how it is structured. Chapter 4 explains the creation of the chemical database. The U.S. Environmental Protection Agency (USEPA) guideline emission and air dispersion models are modified for application to extreme meteorological conditions such as calm and inversion conditions, which are common in the border region. These models and their applicability's are discussed in Chapters 5 and 6. Chapter 7 presents the details of the expert systems approach and discusses with demonstrations the GIS-based computer software. Chapter 8 summarizes the

development of this rapid assessment tool for chemical spills incidents, potential application of this research, and future expansion for improvement.

Chapter 2

BACKGROUND

2.1 Legislation

Since the advent of the North American Free Trade Agreement (NAFTA) and General Agreement on Tariffs and Trade (GATT) agreements, the number of manufacturing facilities along the U.S.- Mexico border has increased considerably. These facilities, including chemical manufacturers, drinking water systems, water treatment works, ammonia refrigeration systems, utility operations, federal facilities, and other manufacturers are classified by the USEPA as users and/or producers of extremely hazardous substances (EHSs).

In the U.S., various legislations passed by the government have gotten the industry on the track of safety planning, preparation, and emergency response. The 1990 Clean Air Act Amendment (CAAA) requires any facilities having on-site hazardous chemicals above the specified minimum levels to create and implement a risk management plan (RMP) for the assessment of all possible spills and the consequential response. The Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) regulates the selection of the best spill stabilization controls for hazardous materials. In 1986, the U.S. Congress passed Public Law (PL) 99-499 in which Title III, Emergency Planning and Community Right-to-Know, creates state emergency planning commissions and local emergency planning committees (LEPCs) to put together a system of identification of local facilities and transportation routes where fuels and hazardous chemicals are present[2]. The Federal Emergency Management

Agency (FEMA) was authorized in this piece of legislation to provide funding to research groups for the development of and the transfer to the public sector of technologies that improve on the emergency response to natural and man-made disasters.

2.2 Impacts to the U.S.-Mexico Border Communities

Accidents could occur on-site (within facility premises) or off-site (outside facility premises) during staging, handling, processing, and transportation of EHSs. Atmospheric releases from these accidents could be catastrophic to a border community. The facilities on the U.S. side of the border are required to prepare an RMP for identifying the hazards and minimizing the consequences of the releases within their premises under Section 112(r) of the 1990 CAAA. However, these facilities are not required to address the consequences of any off-site accidents while an off-site transportation incident involving hazardous materials is bound to occur and the threat to the public is imminent. The U.S. Department of Transportation (USDOT) reported that between 1991 and 2000 there were 119,177 highway transportation incidents involving hazardous materials, resulting in 2,912 reported injuries and 110 reported fatalities[6]. The facilities on the Mexican side, however, are not required by any regulations to address the potential hazards associated with on-site or off-site spill accidents, leaving the LEPCs of the international border communities at a loss for information on the operations across the border. A complete community emergency response plan from the LEPC is not possible without an off-site consequence analysis that evaluates specific potential release scenarios, including worst-case and alternative, for each of the facilities in question. The response time lost due to the lack of planning and preparation could be devastating.

2.3 Current Approaches/Standard Industry Models

2.3.1 *Current Approaches*

The current approaches to the assessment and handling of the consequences of a chemical accident deal mainly with prediction and prevention. Methods such as the use of look-up-tables or call-in emergency response hot lines are helpful, yet not always appropriate to the situation. Organizations such as the National Institute for Occupational Safety and Health (NIOSH) and the USDOT have complied valuable information on a multitude of various chemicals, but the notion of a rapid response is difficult to achieve when dealing with a thick book or an automated phone call.

Most current approaches to dispersion modeling are basically applied to the planning stages for chemical spills during the creation of a risk management plan. Real-time response using dispersion modeling is not yet frequently used. The models that are most commonly found in use in the industry are Gaussian-based models, which have some shortcomings as far as release situations are concerned. Nevertheless, a dispersion model's role in a real-time response situation would be the definition of an effected area, or an "impact zone".

2.3.2 *Impact Zone*

A primary concern when dealing with the emergency response is the definition of an impact zone (zone of vulnerability) designated thusly by a critical chemical concentration that is a toxic endpoint of the dispersion from the source. That critical chemical concentration is known as a level of concern (LOC) determined by the

emergency responders based upon established standards and their own professional judgments. NIOSH has defined the concentration that is immediately dangerous to life and health (IDLH) for a chemical as the maximum concentration that a healthy person can be exposed to for 30 minutes without a respirator and without experiencing any severe escape-impairing (such as severe eye or lung irritation) or irreversible health effects[7]. An impact area may be established using one-fifth to one-tenth of the IDLH value. The threshold limit value (TLV) is another indicator of the critical concentration of the chemical of concern. The Occupational Safety and Health Administration (OSHA) also has it's own reference values for these critical chemical concentrations. The American Hygiene Association has developed the Emergency Response Planning Guidelines (ERPG) to help define LOC's. The ERPG are three-tiered standards (ERPG 1,2, and 3) with a 1-hour contact time. It is generally known that the bases for these concentrations are weak and therefore authorities cannot agree on any type of standards. Whatever the choice for a critical concentration, the response coordinator must determine the distance to this toxic endpoint and act in a timely fashion. There are different methods developed over the years to accomplish the determination of the severity of a spill and ultimately the impact zone.

2.3.3 *Prediction and Emergency Response*

In the potentially dangerous world of chemicals, where hazards are concerned, prevention, prediction, and emergency response are key. The prevention aspect was briefly touched upon previously in Section 2.1 of this thesis; the focus is next turned to the prediction and emergency response aspects. Both prediction and emergency response

traditionally use the same methodology, hazard identification and the modeling of the atmospheric dispersion of the hazardous chemical release. The difference between the prediction of and the response to an accidental chemical spill is, of course, the element of time.

The stress involved with an accidental chemical spill due to the many factors inherent with such a situation, can complicate the already difficult task of emergency response. The general procedure in an emergency response situation is[1]:

1.) Identify hazardous substance
2.) Determine safety hazards (use Response Charts)
3.) Determine severity of spill
4.) Apply precautionary measures
5.) Stabilize release situation (a) stop release (b) control release (use Response Charts)
6.) Assess effectiveness of response
7.) Terminate emergency response

The timeliness of the first four steps in this process is the critical factor in the entire procedure.

2.3.4 *Look-Up-Tables*

Some of the first and current methods employed in the spill severity determination process include look-up tables. These tables include definitions and classifications of hazardous materials and the recommended procedure to handle them as well as information for emergency response. Some of these tables may be found in such