# AN INTEGRATED APPROACH TO TECHNOLOGICAL RISK ANALYSIS AND PROTECTIVE ACTION DECISION MAKING

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## ABSTRACT

Chemical warfare agents stored at eight military installations within the continental United States are scheduled to be destroyed through incineration over the next ten years. Extraordinary measures are being taken at all levels of government to ensure the safety of the public during the storage and disposal phases of the project. Key to protection of the public is development of protective action (PA) strategies, which must be determined prior to and implemented immediately following an accidental chemical release. Three sophisticated, interdependent models (that assess atmospheric dispersion of a chemical, traffic evacuation times, and dose reduction attributable to a particular PA) and a structured operational protocol have been provided to aid planning and management staff in this decision-making process. To equip individuals to utilize both the models and the protocol, a comprehensive instructional program has been developed that examines the risk–impact–response relationship and provides practice in use of the analytical tools. This instructional program may be able to serve as a prototype for use by other communities and chemical locations needing to analyze and plan for response to risks posed by the presence of hazardous substances.

## INTRODUCTION

Within the United States there is ever-increasing recognition that with use of industrial chemicals in comes responsibility to protect the public from risks inherent in such use. Emphasis is being placed on developing and implementing "risk management plans" to reduce the likelihood and impact of accidental releases. Government agencies are issuing regulations and instituting programs to foster emergency preparedness within both the public and private sectors, and to encourage sharing of information between those responsible for chemical safety and accident prevention and those at risk. National and community-based organizations are assuming more vocal and proactive roles in ensuring all parties know of and effectively execute their respective obligations.

Prior to November 15, 1990, voluntary as well as limited, legally-imposed practices already were in place in many facilities that use hazardous materials. That day, however, saw enactment of amendments to the United States' Clean Air Act. Those amendments heralded the beginning of a more aggressive era in enforcement of a comprehensive suite of government requirements designed to further strengthen chemical safety

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management at operations that produce, handle, process or store certain hazardous substances. To fulfill their obligations under the law, qualifying chemical facilities must make projections about the risks they pose to nearby communities. They must undertake and widely share the results of a risk analysis yielding information that permits questions such as the following to be answered: *Where is an accident plume likely to travel? What risk does it pose to the health of exposed persons? Can people be evacuated before the plume reaches them? What is the optimum PA strategy to recommend given a particular set of circumstances?*

No longer is a narrow understanding of or limited focus on the problem acceptable. The new approach presents monumental challenges to all involved parties—those (often non-technical staff) who must perform and document the analyses and subsequently undergo intensive and extensive scrutiny, those who must develop and document response plans and subsequently ensure community members they will be protected, and those who are identified as being at risk and subsequently must evaluate the adequacy of information they receive about risks and planned PAs.

Although 1990 brought a heightened federal emphasis on protecting the public from chemical accidents, Congress years earlier had made its position quite clear on the matter. In 1985 it directed that *maximum protection* be provided the civilian population living adjacent to military locations where chemical warfare agents were stored and destined for destruction (US Army, 1987). This gave rise to the Chemical Stockpile Emergency Preparedness Program (CSEPP), a tri-partite undertaking of the US Army, Federal Emergency Management Agency and ten states.

Drawing upon the experiences gained in preparing jurisdictions within these ten states to conduct such critical analyses, this paper addresses a multi-faceted program focused on the risk–impact–response relationship. In CSEPP, state and local staff (most without extensive scientific orientation) are expected to utilize three sophisticated models and a highly structured "hazard vulnerability analysis" protocol to develop PA strategies to protect people during accidental release of chemical warfare agents stored in eight military installations within the continental United States. While the CSEPP, the chemical agents, the models and the protocol combine to form a situation unique to limited number of states and counties, their existence has served as the impetus for development of a comprehensive planning program and accompanying interactive, multimedia training package that may serve as a prototype for use by other communities and chemical facilities.

## COURSE STRUCTURE

The goal of the Technical Planning and Evaluation (TPE) training course is to provide a framework that can be used in analyzing chemical risks, developing PA strategies appropriate for particular circumstances, and for evaluating, modifying and updating existing local emergency management plans [Copenhaver et. al, 1994 (Draft)]. In short, it teaches a PA decision-making process appropriate for the CSEPP.

Designed for both planners and managers, TPE addresses general information on protective action planning and computer forecasting models; analysis of planning standards providing the foundation for the planning process; interactive, computerized tutorials on the different models and planning concepts; and skills development to provide participants an opportunity to use the integrated models in analyzing sample scenarios. The course consists of six major modules: Introduction and Key Concepts, Implementing the Standards, Oak Ridge Evacuation Modeling System (OREMS), D2PC (an atmospheric dispersion model developed by the US Army), Protective Action Dose Reduction Estimator (PADRE), and Evaluation. Each module contains two units: a computer-assisted instructional (CAI) unit covering the general concepts and principles; and a workbook-based example that is analyzed utilizing the models themselves, forms developed to guide the process, and job aids that provide additional instruction or data needed to run the models.

Computer-assisted instruction was chosen as the delivery vehicle for two main reasons: the CAI offers opportunity to display concepts visually—cutting through many barriers to learning; it also aids in teaching general use of computers, which is extremely valuable when teaching planners to use computer tools for the first time. The course examines the need for and logic underlying a family of forms, included in an extensive workbook, which have been designed to structure, guide and document the analytical and decision-making process. Data forms are an important part of the process; they provide a structure for the planning effort. Without their use, important data may be lost and replication of decisions and outcomes may be impossible. These forms may, in time, be automated to lessen the burden on the planning staff [Clevenger, et. al, 1994 (Draft)].

## PROTECTIVE ACTION DECISION-MAKING PROCESS

The presence of chemical agents in a community presents an identifiable hazard. This hazard can be measured in terms of an individual's risk of exposure to agent and any subsequent dosage. Various tools (i.e., models), have been developed to examine the interaction of the chemical agent characteristics, environmental conditions and social configurations, and also to help evaluate the effectiveness of various PAs in terms of dosage reduction. The models used as planning tools in TPE were developed within the framework of the PA standards for CSEPP. The CSEPP Planning Guidance and Standards also function as a framework for stating the planning problems, utilizing available tools to suggest solutions to these problems, and then systematically producing plans to address the potential problems. The standards raise three questions intended to guide planners while developing emergency plans:

- What is the critical information needed to make a PA decision?
- How can a planner get this information into an emergency PA plan?
- What features of a plan can allow for speedy decisions to be made during the emergency response phase?

Different PAs are appropriate for different population segments under different emergency conditions. There is not enough time during an emergency to analyze the situation to decide what PAs are appropriate. To deal with this time restriction, the CSEPP PA Decision-Making Standards recommend that the planner/decision maker perform all substantive decision-making tasks during the planning phase. If this is done, at the time of emergency the appropriate sets of predetermined decisions can simply be implemented based on the conditions that apply at that time. The components of a PA Strategy include: what accidents can happen; what meteorological conditions could transport a chemical agent into the communities; and what population needs to be protected, where it is located, and who comprises the population (general population, school children, elderly, handicapped, and institutional residents).

## MODELS USEFUL IN PROTECTIVE ACTION DECISION MAKING

OREMS is a "stand-alone" software system for traffic operations analyses and evacuation time estimate studies associated with population evacuations. The system consists of a set of related programs which operate under a "common shell". This common shell allows the user to create input data files interactively and graphically, to simulate traffic operations during evacuations, and to analyze simulation results interactively and graphically (Rathi, et. al, 1994).

D2PC is a computer program that estimates the downwind hazard from the release of a toxic chemical by simulating the behavior of airborne releases of a chemical agent. Hazard assessment is made in terms of the accumulated dosage or peak concentrations of agent resulting from an instantaneous, continuous, or other type of chemical release. D2PC is an air dispersion model that assumes that when agent is released and begins to travel downwind, it is most concentrated in the middle of the plume and less concentrated further away from the middle of the plume (Whitacre et. al, 1987).

PADRE is a software package that compares the total dosage of chemical agent a person would receive, given a specific emergency response and PA, to the dosage a person would receive if no PA was taken. It evaluates PAs: evacuation, shelter-in-place, and supplemental a option for respiratory protection [Sorensen et. al, 1994 (Draft)].

It is important to stress that models can only aid the planner in developing a good plan. They do not replace sound judgment and planning experience. Models provide useful approximations of real events using a limited amount of information. Models are developed around a given set of assumptions of which the user should be aware. One of the most important steps in using models is collecting the data. Models can help us process information so that we obtain much more from a given set of data than we would without using models. Models help clarify relationships among concepts, and help users see complex interactions more clearly. The planner must be aware of the limits and integrity of this information and the effect that the data limits can have on each of the models. There tends to be an overemphasis by users on the exactness and rigor of the model that is not justified (Kaplan, 1964).

## PLANNING PROCESS: STEPS IN DEVELOPING A PROTECTIVE ACTION STRATEGY PLAN

TPE introduces a ten-step process to follow in developing a PA Strategy Plan containing PA strategies and an emergency decision process. There are two basic PAs available for the public in a chemical emergency: evacuation and shelter. However, these options may be used in conjunction with supplemental protective measures.

Step 1: Developing Initial Accident Categories. In this initial step planners choose a set of beginning values for critical characteristics needed to develop groups of accidents (categories). These characteristics include type and amount of agent, duration of release, windspeed, and stability class. A category of accidents, when evaluated by these planning tools, should include the range of accidents likely to result in the same PA recommendation.

Step 2: Develop Meteorological Categories. Meteorological conditions, which have a great impact on downwind distances at which no deaths would be expected, are important factors in defining accident categories. The downwind distance values produced by a specific set of meteorological conditions can be used to create ranges of meteorological values to be used in developing PA strategies.

Step 3: Use D2PC to Determine Safe Distances for Each Accident. This step uses the model D2PC to calculate the downwind distance to safety. This distance is later used in determining how far people must travel to reach a safe area and, given the speed of travel, how much time it will take for them to be protected.

Step 4: Characterize Subzones. When developing planning subzones, the first subzone chosen for analysis should be the subzone with an at-risk population that is nearest to a potential chemical agent release. It is then appropriate to move to subzones that have the next nearest at-risk population until you have planned for your entire location. To complete this step, planners must develop planning assumptions for each planning subzone, identify population and population subgroups, and develop PADRE assumptions for each subgroup/PA combination. It is in developing assumptions for use in PADRE that information from D2PC and OREMS is integrated into this ten-step process.

Step 5: Run PADRE. In this step, the PADRE model is used to calculate the expected dose and the relative number of people affected if no PA is taken; the expected dose and relative number of people who receive a reduced dose if specified PAs are taken; and the relative number of people who, due to implementation of the PA, receive no dose or are protected when the plume arrives. PADRE is the central model in the development of PA strategies.

Step 6: Use PADRE Results to Complete a Protective Action Table (Matrix) for the Planning Subzone. In this step, planners compare PADRE output to values collected on health effects of the chemical agents to see if the reported dose is a significant health hazard in order to determine which of the tested PAs provides the greatest reduction in dose.

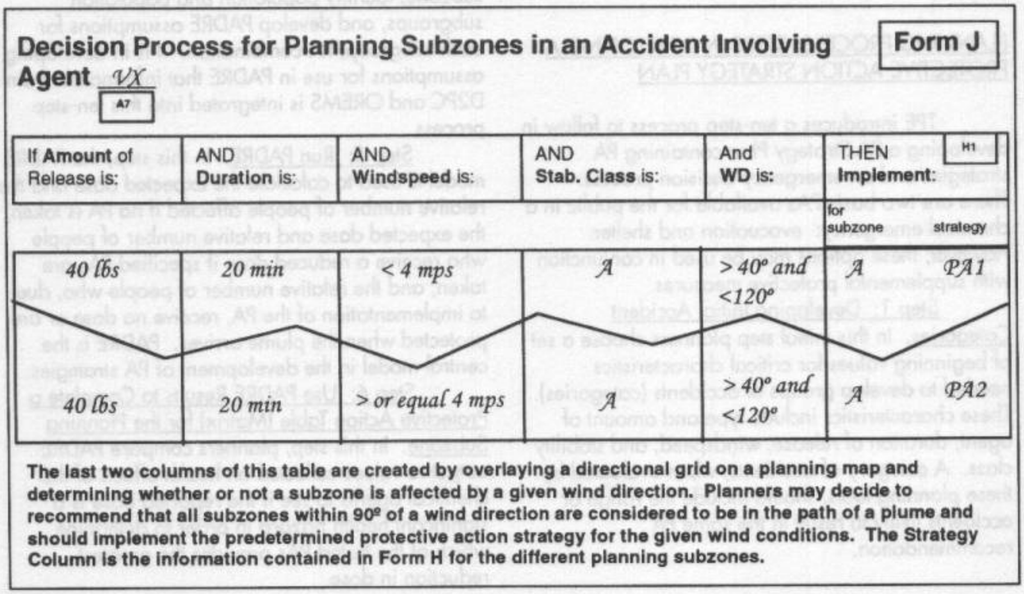
<u>Step 7: Reduce Matrix to Protective Action Checklist for Each Unique Protective Action Strategy for Subzone</u>. The purpose of this step is to group information from the previously generated data into similar PA strategies and document changes in PA recommendations. This step helps to reduce the quantity of information that planners must consider by consolidating model runs with similar PA strategies. This step helps the user determine the lower and upper boundaries of agent amount, duration of release, windspeed, and atmospheric stability class associated with each of the PA recommendations. This determination is based on the PADRE output and comparisons of those values with selected health data values.

<u>Step 8: Prepare Protective Action Summary for Subzone</u>. This step involves entering the data from the *PA Checklists* into a summary table which lists the different PA strategies for the subzone and provides them with unique identifiers. When the *PA Matrix* has been simplified by determining the lower and upper boundaries of agent amount, duration of release, windspeed, and stability class which, in turn, determined the specific PA recommendation, each unique PA Strategy identified by the analysis is entered into a *PA Strategies Summary Table*. This collection of PA recommendations becomes the PA Strategies for the chemical agent storage location.

<u>Step 9: Prepare Decision Process Form for Subzone</u>. This step uses the unique recommendations from the *PA Checklist* and the *Summary of PA Strategies* to document the links between the accident conditions, meteorological characteristics and the recommended PAs. That is, it lists the set on conditions that would lead decision makers to recommend each PA.

<u>Step 10: Prepare Decision Matrix</u>. Once analysis for all planning subzones is completed, it is then possible to create an overall decision table for all subzones (Fig. 1). Step 10 combines the information from different subzones and establishes the links between the accident conditions, meteorological characteristics and the recommended PA strategies. It also links the

Fig. 1 Decision Matrix



**Decision Process for Planning Subzones in an Accident Involving Agent** *VX*

A7

**Form J**

| If **Amount** of Release is: | AND **Duration** is: | AND **Windspeed** is: | AND **Stab. Class** is: | And **WD** is: | THEN **Implement:** H1<br>for subzone | <br>strategy |
|---|---|---|---|---|---|---|
| *40 lbs* | *20 min* | *< 4 mps* | *A* | *> 40° and <120°* | *A* | *PA1* |
| *40 lbs* | *20 min* | *> or equal 4 mps* | *A* | *> 40° and <120°* | *A* | *PA2* |

**The last two columns of this table are created by overlaying a directional grid on a planning map and determining whether or not a subzone is affected by a given wind direction. Planners may decide to recommend that all subzones within 90º of a wind direction are considered to be in the path of a plume and should implement the predetermined protective action strategy for the given wind conditions. The Strategy Column is the information contained in Form H for the different planning subzones.**

recommendations back to the planning subzones by indicating wind direction. In the event of a chemical release, this matrix can be consulted quickly to determine what pre-planned PA strategy is to be immediately implemented, given the conditions of the release.

## ROLE OF TRAINING IN TECHNOLOGY TRANSFER AND POLICY IMPLEMENTATION

The challenges inherent in transferring technology (e.g., analytical tools such as the models addressing atmospheric dispersion of accidental releases, forecasting dose reduction from PAs, and forecasting evacuation times based on local conditions) from the hands of experts to lay persons are extensive. Training can play a critical role in facilitating that transfer. When complex technologies such as computer models are to be used to perform tasks and reach policy decisions, training personnel to use those technologies effectively and consistently can make their use routine for decision making by planners and management personnel alike.

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