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MODELLING PROTECTIVE ACTION DECISIONS FOR CHEMICAL WEAPONS ACCIDENTS

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ABSTRACT

This paper describes work to develop a model to estimate dose reduction from implementing alternative protective actions to protect people against an accidental release of chemical warfare agents. The paper concentrates on describing the user interface, data entry and model use.

INTRODUCTION

ORNL has developed a simulation model to evaluate various protective action strategies for chemical weapons accidents (Chester 1988; Sorensen 1988; Rogers et al. 1990; Sorensen and Rogers 1989) The Protective Action Evaluator for Chemical Emergencies (PAECE) model generates estimates of downwind dosage given an accident scenario and exposure reduction given a scenario of human response to the emergency. Imbedded in the system is the Army's gaussian plume atmospheric dispersion code for chemical agents. The initial model was a single run version operating under the DOS operating system. (Rogers and Sharp 1990). To analyze a scenario one must input the entire data set each time the model is run. The user interface is cumbersome and does not allow for near real time application in an emergency.

In September 1991 a version was released that is capable of comparing two protective actions at 5 different downwind distances. Additionally the user can change a single parameter and re-run the model or load a predefined scenario and runs the model. This version runs under the MACINTOSH operating system and is programed in THINK C.

In this paper we will describe the logic structure of the model and demonstrate the new user interface for the model which allows rapid assessment of protective action strategies. A hypothetical accident situations will be simulated and the PAECE model will be used to choose among two different protective action strategies. Future modelling directions will also be discussed.

PROTECTIVE ACTIONS

Protective actions for chemical warfare agents include the following actions:

1. Evacuation: moving by foot or by vehicle outside of the plume exposure area.
   a. Precautionary evacuation: moving to avoid exposure before a release.
   b. Reactive evacuation: moving to avoid exposure after a release.
2. Sheltering: moving into a structure.
   a. Normal sheltering: moving into existing buildings.
   b. Specialized sheltering: commercial tents and other structures designed for protection in a contaminated environment.
   c. Expedient sheltering: makeshift protection using common materials such as tape or wet towels.
   d. Pressurized sheltering: pressurizing a structure to reduce infiltration of vapors.
   e. Enhanced sheltering: reduction of the infiltration rates in structures by weatherization techniques.
3. Respiratory protection: use of a system to remove aerosols and vapors from the air prior to inhalation.
   a. Gas masks: masks with filters or filtering materials.

b. Hoods: bags with fan-driven filters placed over head and sealed at waist and wrists.

c. Filtered Bags: sealable containers with a fan driven filter.

d. Respirator Bags: sealable containers filtered by respiration

e. Mouthpiece respirators: small tubes with filter material inserted into the mouth.

f. Expedient protection: cloth placed over nose and mouth.

4. Protective clothing: to prevent skim exposure to agent.
5. Protective Suits: suits combining respiratory and skin protection
6. Prophylactic drugs: to prevent agent effects before exposure.
7. Antidotes: to counter agent effects after exposure.

MODEL LOGIC

The model structure is depicted in fig. 1. The model has four main components. The first calculates the probability of implementing a protective action over time. The second component estimates the distribution of successful implementation. For example the length of time to evacuate, infiltration rates into various types of shelters, percent of the population who achieve a seal on a face mask and so forth. The third component use an atmospheric dispersion code to calculate the dose of of agent (concentration time integral) at a given downwind distance over a specified length of time. The final component estimates the expected dose given no protection and the expected dose from implementing a protective action given the outputs of the first three components.

DATA INPUT

Time

The user picks the time of day that the accident occurs. The default is the current computer clock time. Time of day is needed to help adjust the timing of warning diffusion as alternative warning mechanism vary in effectiveness by time of day.

Accident

The user defines an accident based on the quantity and duration of release. The accident data input screen is shown in Fig. 2. Accidents can be instantaneous (1-5 seconds) or up to 360 minute in length. The user also defines the downwind distance of interest, the portion of the release assumed to be

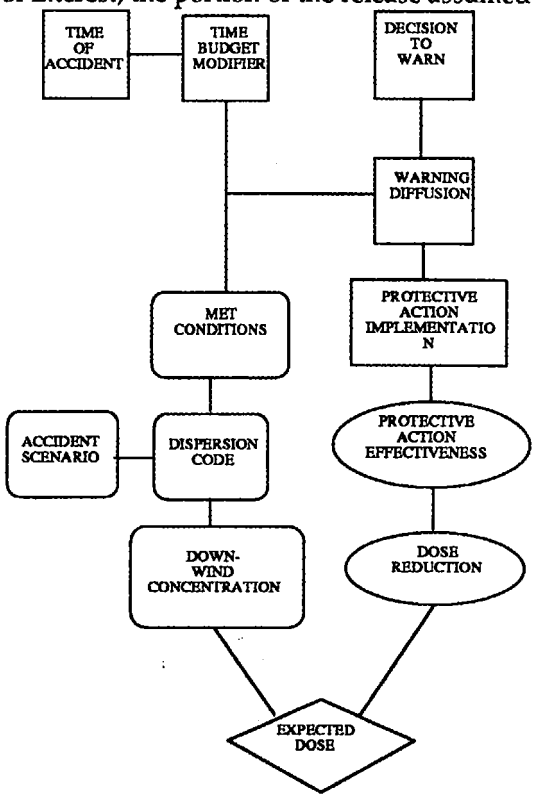

Fig 1. Model Logic

vapor, and the type of agent. The agent type serves to set dose thresholds as the dispersion code does not differentiate among chemical types.

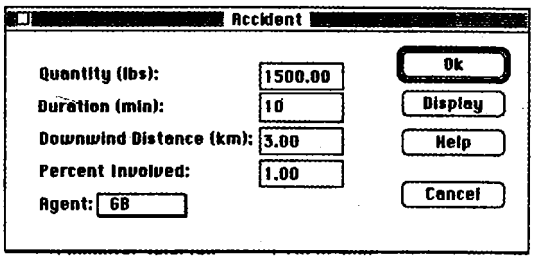

Figure 2: Accident Input Screen

Meteorology

The operational inputs on the meteorological screen include wind speed, mixing height and stability class (Fig. 3). Wind direction will be operationalized in a spatial version of the model which will be developed in 1992. PAECE uses the

Army's "D2PC" atmospheric dispersion code to estimate the downwind concentrations of chemical agents and a routine called "PARDOS" to portion the dose over time. The code is a simple gaussian plume code which assumes the agent is released as a vapor cloud.

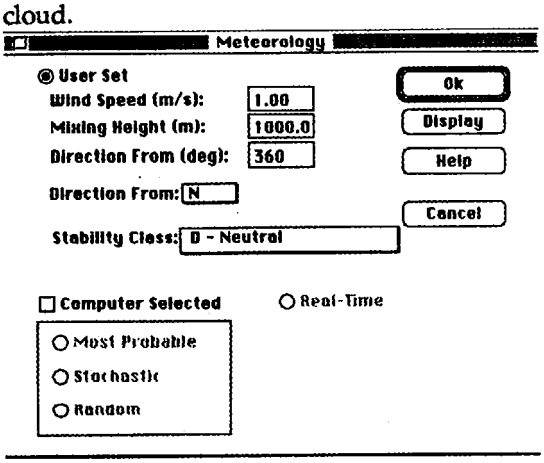

Fig. 3. Meteorological Input Screen

Decision to Warn

The model requires an assumption about the length of time officials take to issue a warning. This is inputted as the time a decision is made with respect to the beginning of the release. The model allows a user to assume the warning is made up to 60 minutes before or after a release.

Warning System

The user must set the parameters in the diffusion equation: $dn/dt=k[a_1(N-n)]+(1-k)[a_2n(N-n)]$. The user has a number of predefined options representing standard warning technologies. These are depicted in Table 1. The coefficients are derived from an approach described in Rogers and Sorensen (1988). The user can set a fixed time interval or delay warning receipt by a fixed amount of time. The input screen is shown in Fig. 4.

Table 1
Parameters Used in the Warning Diffusion Equation
$dn/dt=k[a_1(N-n)]+(1-k)[a_2n(N-n)]$[a]

System	k[b]	a_1[c]	a_2[d]	30-min[e] Lim.	Release[f] Rate(%)
Sirens	0.2	0.2	0.3	0.75	0.3
Tone-alert radios	0.4	0.3	0.2	0.90	0.1
Media	0.3	0.2	0.25	0.50	0.5
Telephones	0.4	0.35	0.2	0.93	0.1
Sirens and tone-alert	0.4	0.3	0.3	0.95	0 .1
Siren and telephone	0.4	0.35	0.3	0.95	0.1

[a]N = population to be warned and n = proportion warned at beginning of period.
[b]k = proportion alerted by broadcast, (1-k) = proportion alerted by contagion.
[c]a_1 summarizes the efficiency of the alerting (broadcast) process.
[d]a_2 summarizes the efficiency of the contagion (birth) process.
[e]30-min limit is a statement constant of first 30 min of warning process.
[f]The rate at which structured constraint is released.

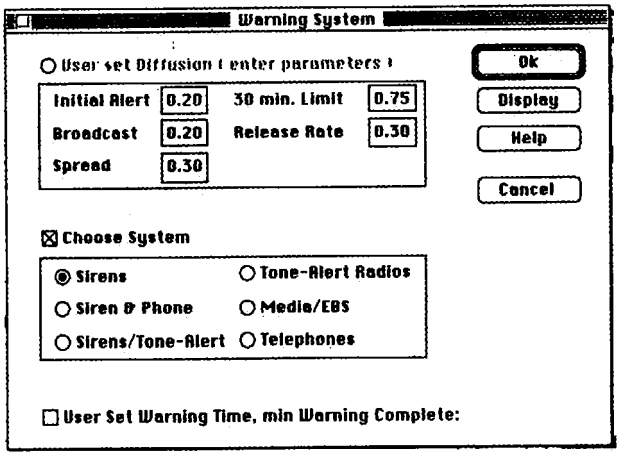

Fig. 4. Warning Input Screen

Public Response

Four historical events are used to derive the parameters for the model. Surveys were conducted after these events to measure the amount of time members of the public took to respond to the emergency following the receipt of a warning. The empirical curves were derived from data collected in three train derailments occurring in Pittsburgh, Pennsylvania; Confluence, Pennsylvania; and Mississauga, Ontario; and a chemical plant fire in Nanticoke, Pennsylvania. The public response in

each of these emergencies involved evacuation. Additional details are found in Rogers and Sorensen (1989). The user can use one of these empirical cases or alter the curves to give more rapid or slower responses (Fig. 5). In addition, response can be set to a fixed time or delayed by a fixed time interval.

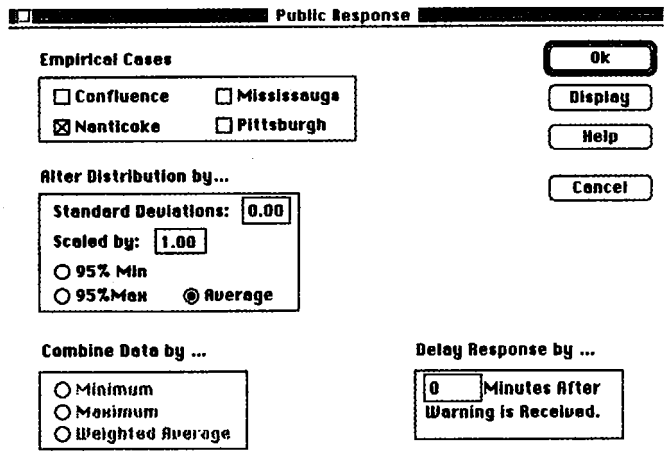

Fig. 5. Public Response Input Screen

Protective Action

The user can evaluate three categories of protective actions: evacuation, sheltering and respiratory protection. Evacuation requires an input of a clearance time (Fig 6). This can be user set or calculated given a speed and distance to safety. Clearance times can be calculated using a quantitative evacuation time estimation model. A variety of models currently exist that will perform this task.

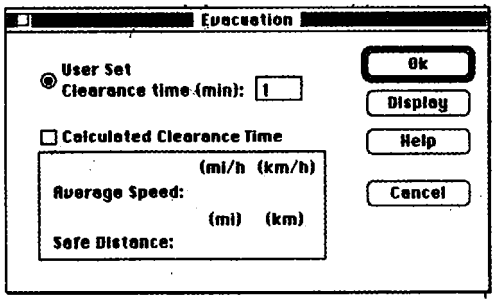

Fig. 6: Evacuation Input Screen

In place shelter requires inputs on the time to complete the sheltering and an air exchange rate (Fig. 7). Time to complete can be inputted as a fixed value or use empirical curves generated by a series of trials conducted on closing up a house as well as taping and sealing a room. The air exchange rate of .15 ACH for a sealed and taped room was also generated by a series of trials measuring the normal and the sealed status air exchange between a room and the remainder of the structure

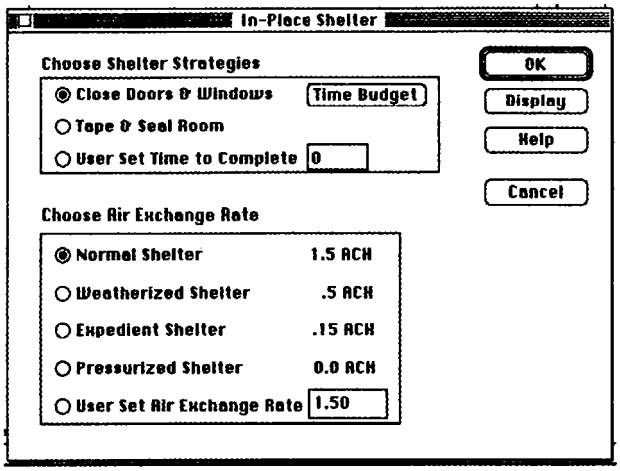

Fig. 7 Shelter Input Screen

Multiple Runs

PAECE is set up to compare two different protective actions at five different downwind distances. The code retains all inputs and calculations in memory so the user can generate either summaries of all ten scenarios or replay the details of each scenario. Fig. 8 shows the screen used to set up a multiple run.

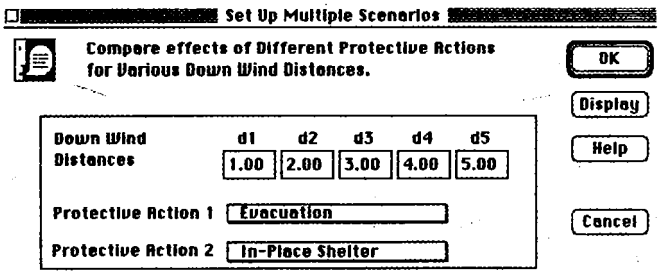

Fig. 8. Multiple Run Input Screen

APPLICATION

To illustrate the use of PAECE a comparison of two protective action will be made. The following assumptions were used in the model:

Time: 9 am
Quantity: 1500 lbs GB agent
Met: 1 mps wind speed; d stability; 1000 m mixing height
Decision to Warn: 10 min. after release
Warning System: Sirens& Tone Alerts
Public Response: Confluence Curve
Evacuation: 60 min. Clearance Time
Shelter: 5 minutes to implement; .15 ACH
Distance: 1;2;3;4; & 5 km

The results are shown in Fig. 9. The chart show the reduction in exposure from an unprotected dose for Protection 1 (evacuation) versus Protection Two (sheltering). In this case sheltering provide a higher expected dose reduction than evacuation.

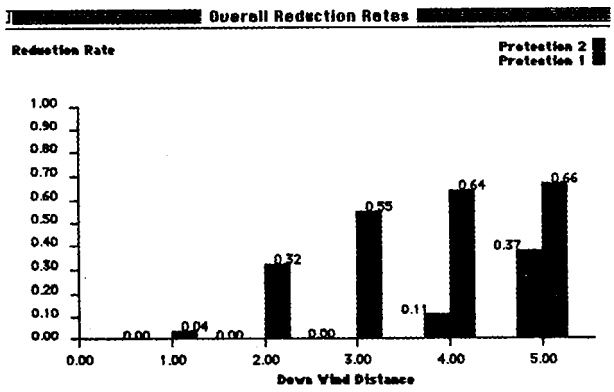

Fig. 9: Dose Reduction Screen

FUTURE DIRECTIONS

Future directions for PAECE include the following:

- Develop a model that will generate point estimates for a 15 sector zone.

- Implement the capability of overlaying the 15 sector zone on the 1990 Census block-level data.

- Develop files with historical met data that can be accessed by PAECE.

- Develop files of accident scenarios that can be accessed by PAECE.

- Develop a windows version of PAECE.

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