PROTECTIVE ACTIONS AND CSEPP: CAN WE SHELTER IN PLACE?

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KEYWORDS

chemical agents, evacuation, sheltering.

ABSTRACT

The public has limited options for protection in an accident involving extremely hazardous chemicals. As previous researchers have suggested, in place sheltering and evacuation are potential options for population protection from a toxic vapor plume. In addition, more attention is being given to several forms of respiratory protection. At least two U. S. companies are marketing respirator devices designed for the general public. Of course European companies have marketed such devices for the past decade. Moreover , the use of gas masks by Israeli citizens during the Gulf War drew media attention to respiratory protection. This paper reports the results of an investigation into the effectiveness of alternative protective actions for chemical weapons accidents. This analysis was done in support of the Chemical Stockpile Emergency Preparedness Program (CSEPP). It is our thesis in this paper that the choice among protective action is a much more complex decision than has been characterized in previous research. Moreover it is highly situation specific and that it is potentially problematic to treat it as a simple decision problem. We hypothesize that it is problematic because a small change in one of the parameters that determines protective action effectiveness may lead to a different decision outcome. Furthermore the list of parameters that influence effectiveness goes well beyond those considered in previous research. This thesis is illustrated by a comparative analysis of evacuation, and in place shelter options. The results show that sheltering is only preferable under very limited conditions, which will be difficult to predict at the time of the emergency.

INTRODUCTION

One of the hottest topics in the area of Hazardous Materials planning over the past several years is whether it is better for people to shelter in place (button-up, in some locales) or to evacuate when confronted with a vapor hazard. A number of guides are available to planners which discuss some of the principles behind planning for protective action decision making. In the Chemical Stockpile Emergency Preparedness Program or CSEPP, a different approach is being developed -- the use of computer simulation models to aid in planning and emergency decision making.

CSEPP was initiated to enhance emergency planning at the 8 sites currently storing chemical weapons. CSEPP is jointly managed by the Army and the Federal Emergency Management Agency (FEMA). It has the ambitious goal of achieving state-of-the-art plans with maximum public protection. It grew out of the Chemical Stockpile Disposal Program (CSDP) which is mandated by Public Law 99-145. The law requires destruction in a manner that maximizes the health and safety of the public. As a result it is critical to plan for accidents in a manner that reduces human exposure to chemical agents should a release occur to the maximum extent possible.

Protective Actions In CSEPP

The basic goal of any emergency management program is to protect people from exposure. Stimulating prompt and effective actions by the public is crucial in achieving this goal. Once the basic protective action options are selected, other activities help implement those protective actions. There are two basic protective actions to a chemical emergency: evacuation and shelter-in-place. Other protective action are also feasible and include respiratory protection, protective clothing antidotes and prophylactic drugs (Sorensen, 1989). These are not considered for use in CSEPP.

Evacuation consists of removing individuals from an area of actual or potential hazard to a safe area and their subsequent return after reentry is approved. It is the most effective of all protective actions provided it is completed before the arrival of the toxic plume. Evacuation may be precautionary or responsive in nature. Precautionary evacuation is desirable because it occurs before the population is at high risk. A responsive evacuation, in contrast, occurs after a release and could expose some or all evacuees to the hazard. Both types entail similar planning tasks: estimating the number of potential evacuees, with particular emphasis on special populations; identifying the most appropriate evacuation routes; designating needed traffic control;

estimating the time needed for evacuation; and anticipating potential problems.

Shelter-in-place is accomplished by shielding the public from exposure pathways for a hazard. This may include from vapors, aerosols and liquid contamination. Shelters may be congregate (for many people) or individualized (a home). Shelters may be existing structures, with or without upgraded protective measures, or facilities specifically designed to provide shelter from toxic chemicals.

In CSEPP there are four types of shelter-in-place: normal, expedient, enhanced, and pressurized. Normal shelter-in-place involves taking cover in a building, closing all doors and windows, and turning off ventilation systems. Effectiveness is improved by going into an interior room. The shelter should be opened up or abandoned after the toxic plume has passed.

Expedient shelter-in-place is similar to normal shelter-in-place except that, after going into the room selected as a shelter at the time of an emergency, the inhabitants take measures to reduce the rate at which air or chemical agent enters the room. Such measures would include taping around doors and windows and covering vents and electrical outlets with plastic. Effectiveness is improved if the room selected as a shelter is an interior room. The shelter should be opened up or abandoned after the plume has passed.

Enhanced shelter-in-place is similar to normal shelter-in-place except that it involves taking shelter in a structure to which weatherization techniques have been applied before the emergency to permanently reduce the rate at which air or chemical agent seeps into the structure. Effectiveness is improved by going into an interior room. The shelter should be opened up or abandoned after the toxic plume has passed.

Pressurized shelter-in-place is similar to normal shelter-in-place except that the infiltration of contaminated air from outside the shelter is effectively prohibited by drawing outside air into the shelter through a filter that removes chemical agent. This filtered air creates a positive pressure in the shelter so that clean air is leaking out instead of contaminated air leaking in.

Appendix D of the CSEPP Planning Guidance defines shelter policy for CSEPP (Oak Ridge National Laboratory and Schneider Engineers, 1994). According to Appendix D, the protective actions to be included in each protective action strategy should be selected according to the following criteria:

a. Evacuation should be recommended under all situations when it can be completed before arrival of the toxic plume.

b. Sheltering options are graphically depicted in Fig. 1. Normal shelter-in-place should be recommended for the general population and for special populations and institutions in the IRZ and PAZ under conditions that would not allow evacuation before the arrival of a potentially life threatening level of chemical agent.

If normal shelter-in-place does not provide adequate protection for any category of accident, members of the general public, institutions, and special populations within the no death distance or within the IRZ boundary if the no death distance exceeds the IRZ are eligible for the Enhanced Shelter Program and/or for expedient sheltering of one room in a house.

Members of the general public, institutions, and special populations who cannot evacuate before the arrival of a potentially life threatening level of chemical agent and who are beyond the no death distance but are in the IRZ or within the no death distance and in the PAZ are eligible for expedient sheltering of one room in a house.

Members of the general public, institutions, and special populations who cannot evacuate before the arrival of a potentially life threatening level of chemical agent and are outside the no death distance in the PAZ are only eligible for normal shelter-in-place.

c. Pressurized/filtered shelter-in-place should be recommended for special populations and institutions within the no death distance who cannot evacuate before the arrival of a potentially life threatening level of chemical agent and for which the measures listed in item b would not provide adequate protection. Facilities/structures that are pressurized would not be eligible for transportation resources to aid an evacuation.

Thus CSEPP does not embrace the concept of collective protection for the general population. The rationale is once people are evacuating it is better to have them leave the area at risk rather than to stop and seek shelter in a collocated facility.

PADRE

PADRE or the Protective Action Dose Reduction Estimator is designed to assist in assessing the conditions under which sheltering in place or evacuation is the preferred action (Sorensen et. al., 1992). To do so it present the user with dialog screens to set accident parameters, to specify the emergency response, and the protective actions employed. PADRE then graphically presents the user with the results of the analysis. The results are portrayed as the accumulation of the outside dosage of a chemical agent over time for someone taking no protective action and for the accumulated dosage given the chosen emergency system and protective action. Various parameters from the model results are displayed graphically and in text form as well. Planners can see when the plume arrives, when it departs,

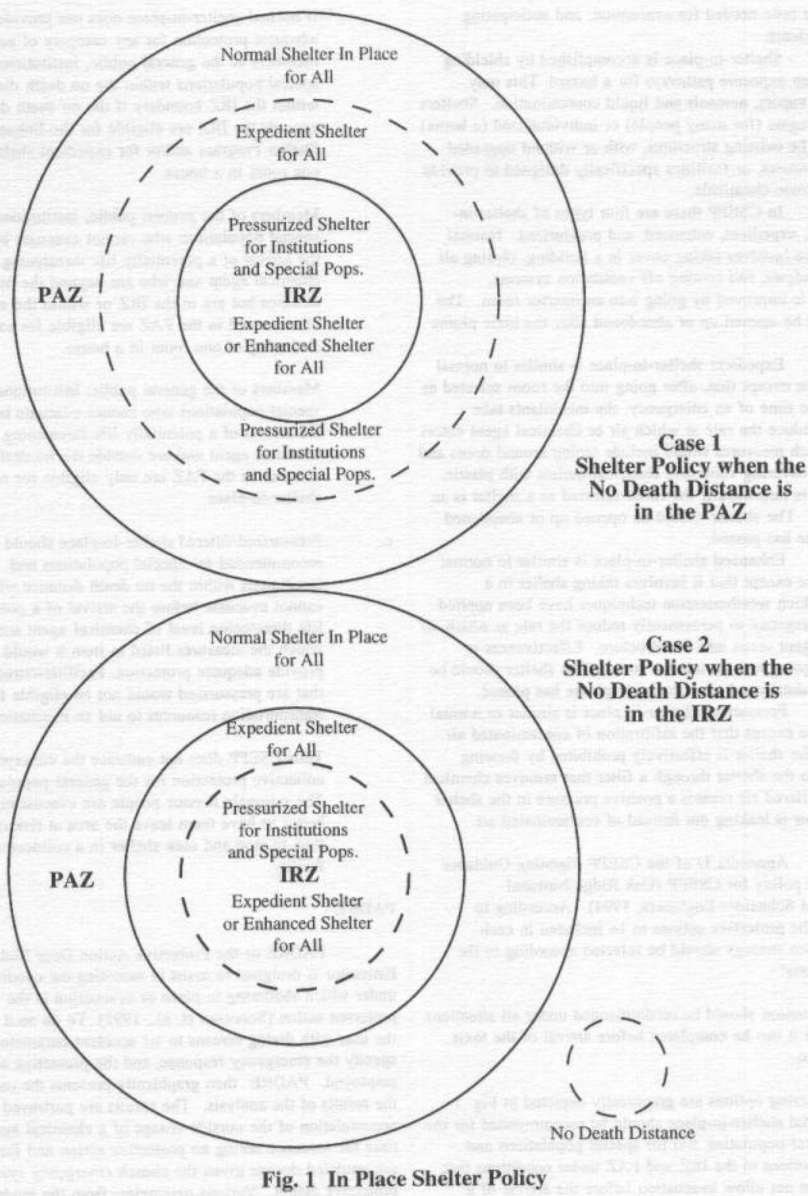

Fig. 1 In Place Shelter Policy

the expected dose reduction from the protective action scenario, and how much more dose savings can be achieved by reducing response time. PADRE allows the user to change scenarios (i.e., different size accidents, different met conditions, different public warning systems, different speed of public response, or different protective actions) and analyze the change in exposure to chemical agents.

The user generates an accident-release scenario, inputs meteorological conditions, and specifies an air exchange rate for a structure. In addition, PADRE takes into account how long officials take to issue a warning, the type of warning system in place to alert the public including sirens, tone alert radios and others, and the speed of public response. For evacuation PADRE calculates a clearance time based on the speed of the traffic and a safe distance. For sheltering, PADRE includes normal sheltering as well as taping and sealing a room. Trials were conducted to measure the reduction in air exchange rates for the tape and seal strategy. In addition, the user may elect to protect people engaged in certain activities such as being home asleep or at work.

Research Questions

In this paper PADRE is used to take a preliminary look at 5 research questions regarding the effectiveness of sheltering in place for chemical weapons accidents:

- Does the relative effectiveness of sheltering decline with the duration of the chemical release?
- Should shelters be vacated or ventilated to reduce dose?
- When is the optimum time to leave a shelter in relationship to plume passage?.
- Do people need timely decision warning and response in order to obtain benefits of shelter?
- Is a poorly implemented shelter strategy worse than standing outside in plume?

Research Results

- Does the relative effectiveness of sheltering decline with the duration of the chemical release?
- Should shelters be vacated or ventilated to reduce dose?
- When is the optimum time to leave a shelter in relationship to plume passage?.

Previous research has suggested it is important to ventilate a shelter after the plume has passed by a shelter (Rogers, et. al. 1990). This is primarily due to the fact that agent is trapped in the shelter when the plume passes by and remains after the plume has gone. People in the shelter are exposed to air contaminated by agent vapors, while the outside air is no longer contaminated.

Work with PADRE suggests a more complex relationship. To minimize dose, the optimum time to vacate a shelter will occur in most cases prior to the plume passage. This will occur at the point in which the concentration outside drops below the concentration inside. At this point the dose accumulates faster in the shelter than in the plume. Thus if a person evacuates near the tail end of the plume passage, they will be better off than if they act "conservatively" and wait until they are sure the plume has totally passed by.

- Do people need timely decision warning and response in order to obtain benefits of shelter?
- Is a poorly implemented shelter strategy worse than standing outside in plume?

Sheltering requires rapid decision making and a quick notification of the public at risk to be implemented prior to plume arrival. The precise speed of decision making and warning to support an effective sheltering strategy will vary with circumstance. What are the consequences, however, of being caught in the process of sheltering? PADRE is used to assess some of the ramifications of slow decision making in a fast moving scenario.

Table one shows the results of a scenario involving the release of chemical agent. The scenario used is a 400 LB puff release under D stability and 1 mps wind speed. The structures involved, located 2 km downwind from the release, have an air exchange rate of 1.5 ach. In the base case scenario we assume that officials make a quick decision (5 min.) to shelter and disseminate the warning using a sophisticated warning system. We also assume a rapid public response to implement the action. In the bases case 76% of those at risk have implemented the action when the plume arrives and the average exposure reduction is 76% of the outside population exposure. If the decision is delayed another 5 minutes the exposure reduction drops only slightly to 70%. However, taking 20 minutes, reduces the exposure reduction to 36%, and for 30 minutes to 3%. Thus delaying the decision has dramatic effects on the effectiveness of sheltering. This is assuming that people vacate the shelter at an optimum time. Table one shows in the base case that sheltering has little exposure reduction if people remain in the shelter. As decision time increases, sheltering has counterproductive effects. With a 30 minute delay in warning, the dose is estimated to be two thirds larger than if a person remained outside in the plume. In this scenario most houses have agent infiltrate before they are closed up, and then people trap the high concentrations in the shelters. As a point of comparison note that a 60 minute delay leads to lower potential for dose increase for a unventilated shelter as the plume passes by before the shelters are closed up.

If we look at the same situation only with a taped and sealed room (infiltration of 0.15 ach), the same pattern is found, albeit with higher protection. Still the benefits of the super tight shelter largely disappear with a 30 minute

Table 1. Effects of alternative decision delays on exposure reduction

	5 min.	10 min	20 min	30 min	60 min
Percent Implemented At Plume Arrival	76	54	3	0	0
1.5 ach					
exposure reduction (%) vacated	76	70	36	2	0
exposure reduction (%) not vacated	3	+8	+40	+67	+32
0.15 ach					
exposure reduction (%) vacated	87	81	44	3	0
exposure reduction (%) not vacated	59	54	17	+23	+20

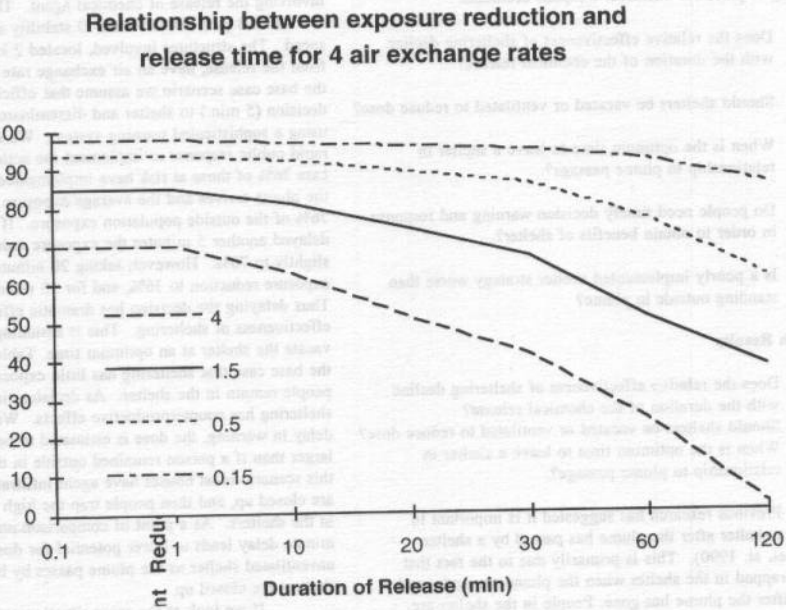

Fig. 2: Exposure Reduction for Different Release Times

delay in warning.

CONCLUSIONS

Shelter is less effective for releases of a longer duration. This is particularly true for structures with relatively high air exchange rates. As the air exchange rate decreases, shelters are viable protection for longer duration releases.

The optimum time to vacate a shelter will likely occur prior to the passage of the tail of the plume. Thus officials are better off to order an early vacating of a shelter than to wait until they are confident the entire plume has passed by.

Sheltering requires attention to the timing of decision making and the ability to warn the public. Delays in a timely decision may cancel out any benefits of shelter or, even worse lead to greater exposure that not sheltering at all.

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