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Evaluation of Warning and Protective Action Implementation Times for Chemical Weapons Accidents

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EVALUATION OF WARNING AND PROTECTIVE ACTION IMPLEMENTATION TIMES FOR CHEMICAL WEAPONS ACCIDENTS

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ABSTRACT

This is a preliminary evaluation of warning systems and protective action options for off-site emergency planning for chemical weapons accidents. The analysis concentrates on the timing of warning and protective action implementation which is defined as the length of time it will take to protect off-site populations given different warning systems and protective action configurations.

The evaluation concludes:

(1) A specialized warning system using tone alert radios, automatic telephone dialing systems, sirens, or some combination thereof is desirable within 10 km of the fixed sites.

(2) A rapid means of respiratory protection and expedient protective sheltering are the protective actions that could be most rapidly implemented within 10 km of a fixed-site release point.

(3) Populations at distances greater than 10 km should have time to evacuate without the installation of specialized warning systems except in institutional facilities such as schools and nursing homes.

(4) The detection and warning decision times are critical elements in determining the feasibility of population protection. A 5-to-15-minute organizational response is needed to provide warning to potentially threatened populations. Even an expedient organizational response, however, will not provide 100% assurance that everyone will have time to learn of the accident and take action.

1. INTRODUCTION

Under P.L. 99-145, the Department of Defense and its executive agent, the Department of the Army, are charged with disposing of the nation's stockpile of lethal chemical agents and munitions by September 30, 1994. In the course of assisting the Department of the Army and its proponent agency, the Program Executive Officer, Program Manager for Chemical Demilitarization prepare environmental documentation for the disposal program, it was determined that existing emergency planning and preparedness needed enhancement in order to reduce casualties in the unlikely event of an accidental chemical agent release (U.S. Army, 1986; U.S. Army, 1987). A significant element of the potential effectiveness of enhanced emergency planning and preparedness involves a determination of how long it would take the public to implement various protective actions (e.g., evacuating, sheltering, and respiratory protection) from the onset of the release.

The purpose of this report is to describe a simple methodology for estimating how long it will take to implement various protective actions. At present, incomplete and poor data limit the ability to understand the feasibility of various protective actions and to analyze the reduction in potential fatalities from implementing any single strategy or a mix of actions. As data are developed, it is important to have a systematic way of organizing the data to come to some informed judgments about protective action feasibility. The analysis in this report serves two purposes. First it allows an assessment of impact reduction from various levels of mitigation. Second, it provides data that can be used in developing decision guides for recommending protective actions in an emergency. While the analysis is preliminary and will be subject to some uncertainties, the method will provide a baseline for further work.

Protective actions for chemical 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. Bags: sealable containers with a fan driven filter.
   d. Mouthpiece respirators: small tubes with filter material inserted into the mouth.
   e. Expedient protection: cloth placed over nose and mouth.

4. Protective clothing: to prevent skin exposure to agent.

5. Prophylactic drugs: to prevent agent effects before exposure.

6. Antidotes: to counter agent effects after exposure.

2. A METHOD FOR ANALYZING PROTECTIVE ACTION EFFECTIVENESS

To establish more refined protective action guidelines, the following steps would typically be followed.

1. Estimate the length of time required to detect and assess each category of credible accidents.

2. Estimate the length of time to disseminate a protective action warning to the public given the available warning system.

3. Estimate the time required to implement alternative protective actions to a reasonable level of protection.

4. For each protective action and accident category, add the time estimates to determine the total time needed for implementing protective actions (this is likely to be a logistic function with time plotted against cumulative percent of the population).

5. Estimate the reduction in exposure due to implementation of the protective action.

6. Prepare time/concentration integrals for each accident class.

7. Compare the needed time with available time for each accident category/protective action combination at various downwind distances and estimate the portion of the public who will have time to take action.

8. Estimate the potential reduction in fatalities from different protective action implementation.

9. Assess appropriateness of different actions for accident classes.

Steps one through four of the analysis are now discussed in greater depth and qualitative assessments of the effectiveness of protective actions are made based on the estimates of time required to take action and the general effectiveness of actions. Limits in data preclude a more rigorous development of the model at this stage.

3. TIMING OF PROTECTIVE ACTION IMPLEMENTATION

3.1 TIME REQUIRED TO ASSESS ACCIDENTS

The length of time it takes to assess accidents can be broken into two categories:

(1) Detection time: the amount of time it takes to recognize that a hazardous situation is about to occur or has occurred, and

(2) Appraisal of threat time: the amount of time that it takes to detect and to decide the situation poses a threat to human safety.

The time required to perform these two tasks will depend on a variety of factors, assuming that training of personnel to recognize and classify an accident or event is adequate. First is the location of the accident or release. An accident can occur at any stage of the disposal process including during storage, inspection of igloos or storage sites, handling of leakers, movement out of storage, loading onto a transport vehicle, unloading that vehicle, during off-site movement, unloading from a transport vehicle, storage at the disposal facility, loading into the disposal facility, and during disposal facility operations.

Second is the type of release. Large explosive releases should be immediately recognized. Spills of agent or vapor releases without an explosion, even large ones may be less noticeable.

Third is the time of day. Nighttime releases will be more difficult to visually detect than daytime release. Personnel may not be present at night to detect a release. The nature of the accident will be more difficult to determine in the dark.

Fourth is the type of detection/monitoring system. Stack monitors will detect any release large enough to threaten off-site populations as well as many more that will not. Monitoring including human observation is more problematic for detecting releases from storage or during movement.

Estimates of these times can be derived from exercises and simulations as well as from observations of previous disasters (see Sorensen and Mileti, 1987; Mileti, Sorensen and Bogard, 1986). It is unlikely that these will be a constant. Instead the distribution of times may differ with respect to location and type of accident, time of day, and level of preparedness. Reasonable estimates for these two time components are presented in Table 1. The basis for these estimates is discussed below.

Table 1. Estimates of appraisal times

System	Time
Detection	
Alarm triggered or visual recognition of cues (trained)	< 2 minutes
Normal visual recognition	< 5 minutes
No detection system	Impact driven 5-60 minutes +
Threat Appraisal	
Automated classification	< 1 minute
Trained human classification	< 5 minutes
Group consultation	15 minutes
Bureaucratic	60 minutes +

The estimates in Table 1 have been derived as follows. The response time for most real time type vapor detectors at levels that would constitute a major release are likely less than 2 minutes. Some technologies are available that would require less than 30 seconds to respond to a chemical agent threat (NRC, 1984). Visual recognition of an event by a trained individual using either cues or instrumentation would likely be fairly quick. The National Weather Service forecasters recognize a flash flood from stream gauge data or a tornado from a doppler radar almost instantaneously. If the event is not revealed by instruments or visual sighting, detection can take a longer and highly variable amount of time (Sorensen and Mileti, 1987).

Threat appraisal can be automated by a computer program that classifies instrument or monitor data into a prediction or category of event. A variety of these systems are used for a variety of hazards and emergency management systems. A good automated threat appraisal response time is less than a minute, although this depends on the complexity of the problem and the speed of the computer. Threat appraisal by a trained individual can also be done in a fairly rapid manner. If the appraisal involves group consultation the time will increase. Experience in the nuclear industry based on simulation exercises suggests that this may take 15 minutes. In situations where ambiguous data and cues are present, coupled with poor training and lack of planning, this process may balloon into an hour or longer depending on the situation.

3.2 TIME TO DISSEMINATE A PROTECTIVE ACTION WARNING

The process of warning the public is not accomplished in a single stage. Typically warnings are issued by civilian authorities with emergency or police powers. This can vary with respect to state and local laws and customs. In this section various warning methods are reviewed and a model of warning dissemination times is developed.

3.2.1 Warning Methods

A variety of communication technologies exist to facilitate the warning process as described in FEMA/REP-10 (FEMA, 1985). To summarize, these include the following:

- Personal notification
- Loudspeakers/public address (PA) systems
- Radio
- Tone alert radio
- Television
- Cable override
- Telephone - automatic dialers
- Sirens/alarms
- Signs
- Modulated power lines
- Aircraft

A brief discussion of each method, adopted from Mileti and Sorensen (1987), outlines the advantages and disadvantages.

3.2.1.1 Personal notification

Personal notification involves using emergency personnel to go door to door or to groups of people to deliver a personal warning message. This type of warning mechanism can be used in sparsely populated areas, in areas with a large seasonal or diurnal population such as a recreation area, or in areas that are not covered by electronic warning capabilities.

The chief advantage of personal contact is that people are more willing to respond to a warning because they are more likely to believe that a danger exists. The disadvantages are that it is time consuming to implement this method, and it may require the commitment of many vehicles and personnel.

To support implementation of this method, it is desirable to develop a plan to systematically traverse the threatened area and issue the warning beginning with the highest risk zone and proceeding to the lower risk zones. A trial run is useful to establish the warning time needed to notify the population at risk, and to establish a notification rate for different types of areas at risk (e.g., heavily versus sparsely populated areas).

3.2.1.2 Loudspeakers/PA systems

It is feasible to use existing public address systems to notify people in areas which are covered by such systems. This may include various institutional populations or commercial establishments. Often schools, hospitals, prisons, nursing homes, sports arenas, theaters or shopping centers have PA systems. In addition, portable loudspeakers can be used from vehicles to warn nearby populations. Often these are used in conjunction with personal notification procedures.

Existing PA systems can supplement can other warning system communication networks. They are useful in reaching small segments of the population in confined settings. To be effective, a link that ensures quick and accurate message dissemination is needed. Without a good communications link to the operators, public address systems are not highly useful.

Portable loudspeakers increase the speed of warning populations without other means to receive the warning. They are particularly useful during nighttime hours when many people are asleep. Their chief disadvantages are that it is often difficult for people to hear a warning broadcast from a moving vehicle and it is difficult for people to confirm the warning, particularly if they only heard a part of it.

3.2.1.3 Radio

Radio is often a major channel for disseminating warning information because it can quickly reach a large number of people during non-sleeping hours. Certain radio stations have been designated Emergency Broadcast Stations as part of the National Warning System (NAWAS) system. These stations usually have arrangements with local civil defense offices or other government agencies to broadcast emergency warnings for most hazard situations. Other radio stations usually broadcast warnings in most situations as well.

The use of radio as a warning channel will continue to be a major practice in emergencies. Often pre-arranged plans for notification and use of standardized messages accelerate the speed in which a warning can be issued over the radio. One disadvantage of the radio is that often a broad area including areas not at risk is covered by the broadcast. Second, all information must be conveyed verbally which excludes the use of graphic materials. Third, radio reaches only a small portion of the population during nighttime hours. Fourth, due to the private operations of stations, problems can arise in priorities regarding warning broadcasts, although this can be largely eliminated with formal agreements and exercises. Fifth, a large segment of the population does not listen to radio.

3.2.1.4 Tone alert radio

Tone alert radios are a specialized warning device that can be remotely activated. They provide a warning signal, and some types can subsequently broadcast a verbal warning message. The radio operates in a standby condition. Upon receipt of a code, the radio emits a tone and broadcasts a prerecorded or read message. The code and message are broadcast from a radio transmitter which typically has a range of 40 miles. The radio receivers operate on normal electrical power and some have battery back-ups.

An example of an existing tone alert system is National Oceanic and Atmospheric Administration (NOAA) weather radio. This system covers a major portion of the population within the country. Its chief function is to provide continuous weather forecasts. The National Weather Service (NWS), however, can activate radio receivers to issue warnings regarding severe weather. This system can, by prearrangement with the NWS, be used to issue warnings for other hazards such as nuclear attack or nuclear power accidents.

The advantages of the tone-alert systems include a quick dissemination time, the combination of an alerting signal with specialized messages, and their round-the-clock availability. Disadvantages include maintenance problems, availability during power failures, and difficulty for using outdoors. The radio receivers are relatively inexpensive, costing less than $50 for NOAA radio receivers to about $300 for special dedicated receivers with a battery backup.

3.2.1.5 Television

Warnings are also broadcast over commercial television (TV). This can be done by interrupting normal programing or by displaying scrolled text on the bottom of the screen. Television reaches a large number of people, particularly in the evening hours. Like radio, it is a poor channel during sleeping hours.

Television is a particularly good channel for warnings of slowly developing events. It is likely to take longer to issue a warning over TV stations except where pre-written scrolled messages are used. One major advantage of TV is the ability to use graphic information such as maps or diagrams in the warning.

3.2.1.6 Cable TV override

In many urban areas people watch cable TV. This means that local stations play a more minor role in reaching the public. As a result systems have been developed for a cable TV company to issue a scrolled or broadcast message over all cable channels. Thus a person in Cheyenne, Wyoming, watching a Chicago station or a movie channel could still receive a tornado warning through the local cable station.

Usually the override systems are operated by local civil defense offices in coordination with a cable TV station. This requires prearranged conditions and agreements on the use of such systems. The same advantages and disadvantages of normal TV apply.

3.2.1.7 Telephone - automatic dialers

Switching and automatic dialing equipment that is currently available could be used to reach potentially a large number of people in a relatively short time frame. Technology has recently been developed that is capable of simultaneously calling hundreds to thousands of exchanges using automatic switching equipment. Some systems will automatically hang up phones in use and block out incoming calls during the transmission of the emergency message. These systems make use of existing private party phone lines and telephones. Almost all of the modifications and special equipment are installed at the phone company. These systems play prerecorded messages which can be updated fairly quickly, or live broadcasted messages, providing timely information. It is also feasible to have them use a special ring that would act as an alerting function. They can also be combined with the use of telephone hot-lines to provide specialized information as well.

The chief advantage of telephone warning systems is the ability to quickly disseminate a message to people at home. Automatic dialing systems, however, are expensive and primarily limited in their use by cost factors. It is unclear what fraction of a large local area phone system can be simultaneously contacted. Another problem to consider is that people who are not near a phone will not receive a message. Due to these issues automatic telephone systems are currently used chiefly to warn persons within an interorganizational network such as emergency response personnel or institutional facilities at risk. Recent developments make this an attractive option for small communities or for areas of a community where a prompt warning is needed.

3.2.1.8 Sirens/alarms

Considerable information and data exist on the technology of siren and alarm systems and will not be repeated (Voorhees, 1982). Technology exists to provide an audible signal to most populations at risk, although it may be expensive to implement the technology. These types of warning devices are designed to provide a very rapid alert to the potentially threatened population. A few types of sirens have the potentially threatened population. A few types of sirens have public address capabilities as well, but most only sound a noise.

Siren systems are limited in their utility by the lack of instructional messages. At best they tell people to seek further information unless an intensive program of public education is used to instruct people what to do when the signal sounds. This may be possible in situations when the same response would be desired every time a warning is issued. Multiple signals, such as a wavering signal versus short blasts are rarely differentiated by the public. Reliance on different signals to evoke different responses as a warning strategy is done on fairly weak empirical grounds.

Other problems that constrain the use of sirens and alarms are false alarms due to technical failures, equipment failures in emergencies, maintenance problems, coverage problems (particularly in adverse weather), difficulties in propagating sounds into buildings, and public indifference to sirens. Despite all these problems, siren systems are a main component of many warning systems in use today.

3.2.1.9 Signs

Often warnings cannot be directly communicated to publics in remote hazardous areas. This has prompted the use of permanent warning signs which instruct people about how to recognize the onset of a hazard and what to do if one occurs. Signs can be effective warning devices if they are in the proper locations for people to see and if they are visible at the time an emergency occurs. In addition, signs may serve as a valuable educational device; people who see them frequently may learn what to do in an emergency without needing a specialized warning. Problems with signs include periodic maintenance and replacement and identifying the proper locations to place signs.

3.2.1.10 Modulated power lines

Existing electrical power distribution technology enables specialized warning systems which utilize power line modulations to activate an alert system. When the system cycle-per-second frequency is altered, devices linked to electrical circuits can be activated to turn on a radio, a warning light, or a buzzer or siren. Many of the advantages of tone alert systems hold for this type of warning device. Modulated power line technology, however, is relatively expensive to install, test, and maintain. In addition, it cannot be used if electrical systems fail.

3.2.1.11 Aircraft

In special cases airplane and helicopters can be used as part of the warning process. Sirens or bullhorns can be carried by low-flying aircraft to provide an alert or warning message. In addition, they could drop prepared leaflets containing a warning message. This type of warning channel is useful in reaching remote populations or populations that cannot be reached by normal communication channels. Disadvantages include access to aircraft, maintenance, and cost. A further problem is obtaining sound systems which can broadcast a message that can be heard over the noise of the aircraft itself.

3.2.1.12 Summary

Based on these assessments it appears that the following systems should be examined to determine their applicability to the chemical weapons emergency planning concept:

Personal notification (or door to door)
Loudspeakers/PA systems (route alert)
Tone alert radio
Mass media (radio, TV)
Telephone automatic dialers
Sirens/alarms with media broadcast.

3.2.2 Warning Time Estimates

The process of warning can be broken into the following stages or time frames:

- Time for notification of warning officials: the amount of time it takes to notify the person with warning responsibilities that the problem exists and describe the problem.

- Time for warning/protective action decisions: the amount of time it takes to locate all who will make a warning decision and for that decision to be made.

- Time for warning dissemination: the amount of time required to prepare a warning statement and disseminate it to people at risk. (This will vary with method of warning and geographical locations of subgroups of the population.)

This, however, may present an overly structured view of the warning process. We know that people respond to cues such as a plume of smoke as well as formal (from officials) and informal (from friends or relatives) warnings in emergencies. Furthermore, informal warnings may come before the official one. In addition, the public plays a role in informing other members of the public. Despite such caveats, it is possible to develop estimates of warning time based on the communication hardware systems available, performances during simulation exercises and case studies of actual warning experiences.

3.2.2.1 Notification of warning officials time

Under ideal conditions, this can be done within a minute or two if the following conditions prevail. First, there exists 24-hour emergency staffing of communication channels. Second, there is dedicated communications equipment and a back-up system. Third, personnel are trained to communicate automatically. As these conditions are relaxed, the likelihood of longer times increases. Another option is to have a facility-based decision in which the legal authority for making a decision is given by the community to the installation, thus eliminating this step of the emergency response.

3.2.2.2 Warning/protective action decision time

The length of time to make a decision is determined by the nature of the decision making structure, the number of people involved, and their availability. An automated decision aid can provide a rather quick decision under a limited set of circumstances. For the most part, however, this is a human decision. If the hazard detectors, in this case the on-site personnel, make the decision, the time is minimized to between 5 and 15 minutes given proper training. A well prepared off-site group can perform in the same time frame. If the local emergency officials must gather and decide, it may take up to an hour to make a decision. Many case studies illustrate this type of delay and the factors that lead to this delay. Table 2 summarizes the notification and decision times.

Table 2. Notification and decision times

	Time
Notification	
1. By pass	0 minutes
2. Off-site with training/equipment	< 5 minutes
3. Off-site with problems	15 minutes +
Decision	
1. Automated	< 2 minutes
2. Individual with training	< 5 minutes
3. Small Group with training	< 15 minutes
4. Larger ad-hoc group	15-60 minutes +

3.2.2.3 Warning dissemination time

Estimated average times, to reach 25, 50 75 and 90% of a population with a warning message (not an alert signal) are shown in Table 3. These are presented as ranges to reflect some uncertainty and expected variances, however these ranges are not statistically derived. They represent "best guess" upper and lower bounds based on available historical observations and judgement. These times assume resources are commensurate with population density and size of the emergency planning zone (EPZ) and a good warning plan has been developed and maintained. These require adjustment and fine tuning given site-specific factors. To summarize the time required to reach 90% of a population are as follows:

Personal notification: 2.5-3 hours
Loudspeakers/PA systems (route alert): 1.5-2.5 hours
Tone alert radio: 10-15 minutes
Mass media: 3-4 hours (except at night)
Telephone automatic dialers: 10-15 minutes
Sirens/alarms with media broadcast: 20-35 minutes
Sirens with predetermined response: 10-15 minutes

Table 3. Estimates of warning dissemination times for alternative systems (in minutes)

Warning system	Percent of population warned[a]			
	25	50	75	90
Media	20-30	45-60	80-120	180-240
Door to door	40-45	60-80	100-120	150-180
Route alert	25-35	40-50	60-70	90-150
Tone alert radio or auto telephone	2-3	4-5	7-10	10-15
Siren/media	5-10	12-15	15-20	20-35
Siren/fixed response	1-2	2-3	4-5	10-15

[a]Under good weather conditions and assuming systems that are maintained.

These times represent average conditions. There are situations in which the times could be slightly quicker or somewhat longer. Door to door or route notification would take a longer time under adverse weather conditions. Media notification is highly dependent on the time of day. Sirens are less effective during the nighttime when houses are closed up. Tone alerts are less effective during the day when people are outside or in vehicles.

3.3 TIME REQUIRED TO IMPLEMENT PROTECTIVE ACTIONS

The next phase of our model is the period in which the public implements the recommended action. Since people do not always respond to a protective action recommendation immediately, this can be viewed as two stages:

- Protective action decision and preparation time: The amount of time it takes the public to decide what protective action to take and to mobilize the resources to implement the action.

- Protective action implementation time: The amount of time it takes to implement a protective action to a level of reasonable safety. Time estimates for different types of protective actions discussed earlier can be approximated from historical data.

3.3.1 Evacuation

Protective action decision and preparation time: The best data regarding mobilization time in a quick onset event comes from the Mississauga, Canada, chlorine rail-tanker accident. The experience suggests that about 40% of the population took almost immediate action, 65% had evacuated after 30 minutes, and almost 90% had evacuated 45 minutes after being warned.

Protective action implementation time: The time it takes to evacuate an area is a function of many variables including mode of transit, loading estimates, traffic network geometry, route choice, direction of the movement, road capacity and demand, vehicle speed, and number of vehicles used. This can only be calculated on a site specific basis. In low or medium population density area, this time is likely not to be significant if evacuees move both out and away from the plume line. Vehicle speed will likely exceed that of the plume. In high population density locations, evacuation logistics is a thornier problem.

3.3.2 Sheltering

Protective action decision and preparation time: This is close to zero if the shelter is prepared and maintained or is an existing structure. Portable shelters can take longer to prepare. It is estimated that a portable shelter would require at least 15 to 30 minutes (or longer for some models) to erect after they were located. Pre-positioning and/or partial pre-erection could reduce this time. A positive pressure system could be set up to be activated without much preparation time. To support expedient sheltering, it would take about 5 minutes to locate and assemble materials.

Protective action implementation time: Sheltering involves closing doors and windows and shutting off ventilation systems. This could likely be done in less than 10 minutes. Movement into a prepared shelter would not take very long to accomplish once it is available. A positive pressure system could be activated fairly quickly and should not take more than 5 minutes. Implementing expedient sheltering would take about 5 minutes to tape a door and about 3 minutes to tape a window. An additional few minutes would be needed to wet a towel and lay across the bottom of a door. An average room could probably be sealed in 10 to 15 minutes

3.3.3 Respiratory Protection

Protective action decision and preparation time: It is expected that the time required to make a decision to use and locate protective equipment would be relatively short given a good warning, instruction, proper education, and training about their uses. A reasonable estimate is 5 minutes or less.

Protective action implementation time: Once the equipment is located, it can be quickly put to use in less than 5 minutes and in many cases less than 2 minutes with adequate training. Respiratory mouthpieces take only seconds to insert. A gas mask may take as much as ten minutes, however training can reduce this to less than one minute. If the protective equipment is misplaced the implementation time will be longer. Expedient measures can be applied in a few seconds.

3.3.4 Protective Clothing

Protective action decision and preparation time: This would be similar to the time required to locate respiratory protection devices. Estimated time is 5 minutes.

Protective action implementation time: Depending on its complexity, a suit would take 5 to 10 minutes time to put on.

3.3.5 Prophylactic Drugs and Antidotes

Protective action decision and preparation time: If prophylactic drugs or antidotes were available and distributed to the public it would probably take less than 5 minutes to locate the drugs. Some people would probably not be able to find the drugs, albeit the portion is unknown. If drugs were available for distribution by only trained medical personnel it is likely that it would take several hours to distribute them.

Protective action implementation time: This would likely require less than one minute after the drugs are distributed.

3.3.6 Summary

The implementation of a protective action will not occur simultaneously for an entire population. The timing of the implementation typically follows a logistic-type function over time which can be approximated by a linear or log function. The steepness of the curve is a function of the degree of impending threat and the logistics of taking the action. Not 100% of the population will take protective actions. Studies have shown the percent adopting a measure is a function of the level of threat and other factors. In a high threat situation, it is reasonable to assume that between 90 and 100% of the population at risk will implement some form of protection.

3.4 TOTAL PROTECTIVE ACTION IMPLEMENTATION TIME

Estimates of total protective action implementation time are basically functions of receiving the warning and taking the action. These can be represented as sums of the times to detect, appraise, notify, and decide and the variable times to warn and implement the action. The representation is:

> time to protect x % of the population = detection time (dt) + appraisal time (at) + notification time (nt) + decision making time (dmt) + response time (rt) [where rt = (warning time$_{\text{method } y,\ x\%}$ + protective action time$_{\text{action } z,\ x\%}$)].

The quickest amount of time to protect the population without development of new technologies would be a system in which individuals were trained to recognize and classify an accident and make a warning decision. A decision to warn would be a prompt alert of the public using an audio device which would mean that an individual should use a mouthpiece respirator or another suitable means of rapid protection and turn on the radio to find out what to do next. It would be technically feasible, according to the estimated times for each stage of the process, to warn 90% of a population within a 15-minute-time period following detection. Calculations of the number of people protected in any given time or the time to protect a given percentage of the population can be made under a variety of assumptions regarding the variables in the formula.

Examples of calculations based on values provided earlier are found in Table 4. These are provided for different scenarios. The first scenario assumes the quickest response possible. Using specialized decision and warning systems and respiratory protection, a high degree of protection can be rapidly achieved. A second scenario depicts a good emergency system responding to an incident in which non-immediate life threatening conditions prevail. The model estimates it would take about three hours to warn and evacuate a population. In scenario 3, one observes that by taking some specialized measures that the response time can be cut significantly over a normal situation. The final scenario depicts what might happen if problems are encountered during the various tasks. In this case 5.5 hours elapse before people are offered some marginal protection through sheltering.

Table 4. Example time estimates to warn and protect 90% of population (in minutes)

	Scenario			
	Least time	Normal emergency	Specialized response	Problem response
Detection	2	5	5	20
Appraisal	1	15	5	60
Notification	0	5	5	15
Decision	2	15	10	45
Warning	10[a]	90[b]	35[c]	180[d]
Total warning	15	130	60	320
Protection action	5[e]	60[f]	10[g]	10[h]
Total time	20	190	70	330

[a]Special.

[b]Route alert.

[c]Siren/media.

[d]Media.

[e]Respiratory protection.

[f]Evacuation.

[g]Shelter/respiratory protection.

[h]Shelter.

4. CONCLUSIONS

4.1 ASSESSMENT OF DECISION AND WARNING SYSTEMS

Most chemical weapons accidents are sudden fast moving events with little precursory activity and rapid release times of one hour or less (MITRE, 1987). It is vital, therefore, to issue a warning in a minimum amount of time that is feasible. This means that a capacity for rapid accident detection, identification, appraisal or classification and decision making is needed. The goal should be to issue a warning within 5 to 15 minutes of detection and have a detection plan such that an accident would be identified within minutes of initiating conditions. In some situations, the ability to issue a warning must be established without a great amount of time devoted to communications and decisions. Arrangements to go directly to the public in fast moving events when normal contact with appropriate officials cannot be made is necessary to support an effective system.

As a result of the potential for rapid accidents, a warning system near the facility boundaries must deliver a message in a minimal amount of time. The best systems are either telephone ring-downs or tone alert radios and siren systems. New telephone warning technologies may be capable of prompt alert and notification but have not been fully tested in actual use. The chief advantage of the telephone and tone alert radio is that they provide instructional information. They will not be effective in reaching people outdoors. Tone alert radios must be maintained to assure proper operations. Experience has shown that unless the radios are attached, batteries are replaced and the correct channel used, the system effectiveness is decreased. A siren system may be feasible if it signals a prompt protective action followed by information seeking for further instructions. Sirens pose some problems at night when buildings are closed up.

At greater distances (e.g., greater than 10 k), conventional route notification and door-to-door notification, complemented by media notification, are warranted unless special conditions exist to justify specialized systems. Such conditions could include dense population clusters or institutional facilities.

4.2 ASSESSMENT OF PROTECTIVE ACTIONS

4.2.1 Evacuation

It is likely that evacuation is a feasible action only when more than one hour of time is available to implement a protective action before lethal concentrations of agent are present in the environment. It is likely that evacuation can be used as a precautionary measure or at distances within the plume exposure pathway that allow for one or more hours of response time.

4.2.2 Sheltering

Sufficient time exists to implement sheltering provided that a timely decision and warning are made. Specialized sheltering such as commercial tents and other structures are less feasible because of the time it takes to erect them. Expedient sheltering such as the makeshift taping of rooms could be done if the materials were available. Pressurization of a structure requires little implementation time and, as such, represents the most desirable form of sheltering. Enhanced sheltering by reduction of the infiltration rates could be implemented quickly as well. Both require extensive pre-emergency preparation.

4.2.3 Respiratory Protection

Gas masks, hoods, bags, and mouthpiece respirators all require storage and, hence, some time to locate. Even if distributed, some people would likely fail to find them in an emergency or carry them on a day-to-day basis. Once located, mouthpiece respirators take the least amount of time to use. Bags and hoods can be used relatively quickly as well. They represent a good choice for infants and small children, respectively. Face masks require slightly longer time on the average to use. Expedient protection is an action most people can take immediately.

4.2.4 Protective Clothing

If available protective clothing can be donned fairly quickly with some practice. The provision of such equipment should be based on whether it is effective and needed to reduce risk of exposure.

4.2.5 Prophylactic Drugs and Antidotes

Timing of implementation is not a constraint for uses of drugs if they are pre-distributed. It is likely that some would fail to locate the drugs in an emergency. If these are to be administered by medical personnel, it is likely that insufficient time would exist to implement this protective action.

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