ORNL/TM-10825

Energy Division

REVIEW OF PUBLIC ALERT SYSTEMS FOR EMERGENCIES AT FIXED CHEMICAL FACILITIES

John H. Sorensen
George O. Rogers
William F. Clevenger

Date Published: July 1988

Prepared for the
U.S. Environmental Protection Agreement
under Contract No. 1824-1643-A1
with the Cooperation of the
Federal Emergency Management Agency

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
Under Contract No. DE-AC05-840R21400

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ABSTRACT

TITLE III of the 1986 Superfund Amendments and Reauthorization Act (SARA) requires communities that have industrial or other facilities that store or use certain hazardous chemicals to develop emergency response plans for chemical accidents. Facilities that have such chemicals are required to disclose information to the communities. As directed by Section 305-b of TITLE III, the U. S. Environmental Protection Agency (EPA) is required to prepare a report to congress reviewing current emergency systems for chemical accidents, including prevention, monitoring, detection and public alert technologies.

The purposes of this study were to assess: (1) the technology used to alert and notify the public in conjunction with chemical release, (2) the procedures used to alert and notify the public in conjunction with a chemical release, (3) the management practices associated with the process used to alert and notify the public in conjunction with a chemical release, and (4) the relationships between facility characteristics, emergency system characteristics, and system effectiveness with respect to alert and notification of the public.

Data for the study was collected from a non-random sample of communities with hazardous facilities. EPA had selected 525 chemical facilities to include in the study using a purposive sampling frame. The sample of communities was selected by matching the facilities to city-level emergency management agencies. When more than one facility was matched to a community or county, a single facility to use as the reference point was chosen. A total sample size of 277 local emergency planning organizations was identified. Responses from 60% of the sample were received. Twenty-three communities did not or no longer had the facility included in the study. The first 137 questionnaires with complete data form the basis for this report.

Five major findings emerged from the study: First, communities do not have the knowledge about what types of information about a chemical accident is needed to make good decisions in an emergency. Too much reliance is placed on making warning and protective action decisions in a crisis setting without prior planning about how that process would occur. Second, communications linkages from both a hardware and a human standpoint between facilities and communities are largely unreliable and

inadequate. Third, plans and implementation procedures at both the facility and in the community are weak or non-existent in many cases and require greater attention. Fourth, many existing alert and notification systems would work to provide a precautionary alert over a several-hours-time period but would fail to provide a timely warning in a sudden accident. Fifth, the response of the public to a warning, particularly in the absence of pre-emergency information is uncertain and potentially problematic.

The improvement of public alert systems is feasible without the development of new technologies. The problem of diffusing existing technology and knowledge is greater at present than the problems created by the lack of appropriate technology. Unless new technologies lead to low cost equipment which could rapidly alert and notify the public, and could be easily installed and maintained, further technological advances would only increase the gap between practices and the state-of-the-art.

1. INTRODUCTION

The purpose of this study is to evaluate (1) the technology and procedures used to alert the public in the event of a chemical release; (2) the management practices associated with these processes; and (3) the relationship between the facility, emergency system characteristics, and system effectiveness.

Data from surveys and secondary sources are used to compare existing public alert and notification systems to the state-of-the-art technology, procedures, and management practices. The research assesses problems and constraints that would interfere with a timely and effective emergency warning and determines where significant improvements can be made in public alert and notification systems or chemical emergencies.

2. A REVIEW OF PUBLIC ALERT AND NOTIFICATION SYSTEMS

This section develops the theoretical basis for the investigation of public alert and notification systems for potential fixed-site chemical emergencies. Three areas are addressed: (1) a systems approach is used to develop a definition of a public alert and notification (warning) system, (2) a framework for evaluating the effectiveness of organizational aspects of alert and notification is developed and, (3) the process of public response to warnings is discussed. The continuation of these three elements provides a state-of-the-art evaluation of the public alert and notification process. The warning process and primary considerations will be discussed, but a comprehensive literature review will not be provided.

2.1 THE WARNING PROCESS

A general model of a warning decision system has been developed by Sorensen and Mileti (in press, b; Mileti et al., 1985). This model defines the general component, common decision points, and links that are characteristic of all warning and protective action decisions. The key decision points and communication links that define the process are illustrated in Fig. 1. The model has three basic components: a detection subsystem, an emergency management subsystem, and a public response subsystem. The initial stage in the decision-making process is the detection of a hazard or the recognition that the environment poses a hazard. Once a hazard is detected, the second key decision is whether the hazard poses a threat. If the threat is judged to be significant, the detector/assessor must decide whether to alert the public or officials of the risk and potential damages and who should be notified of the threat. The notification of a public official typically results in

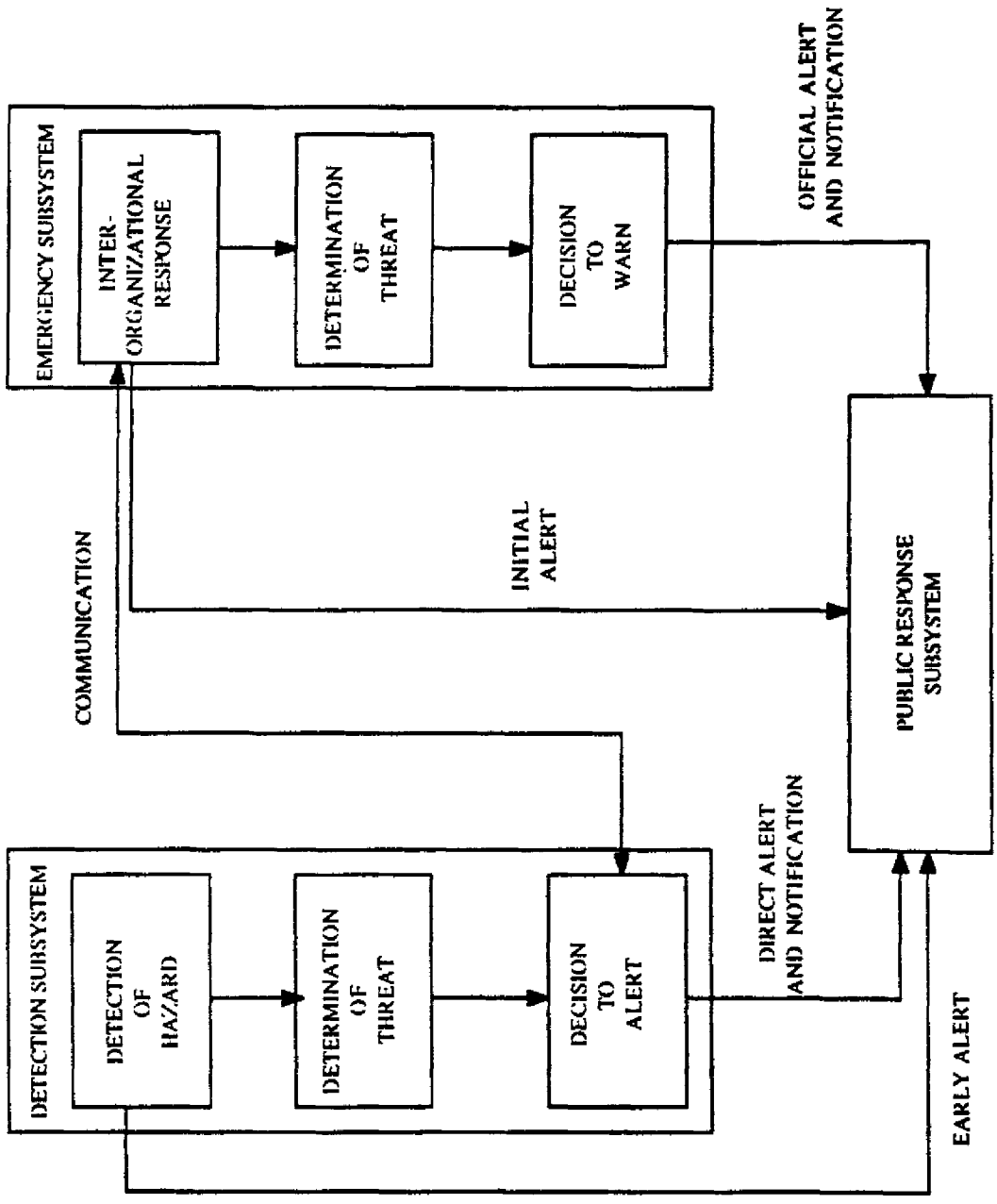

Fig. 1. A general model of key decision points and communication links in the warning process.

the activation of an emergency response system. The organization initially notified must decide if others should be involved in a decision to warn. Once mobilized, a decision must be made by emergency managers whether the risks warrant warning or protective action. Finally, a decision is made about the type of protective action needed, whether to warn the public, and if so, by what process.

This model illustrates that the organizational component of an emergency can range from a simple situation involving a citizen originated detection and alert mechanism to a complex situation involving a large scientific monitoring program accompanied by a bureaucratic government decision structure. The process is often interactive with numerous dynamic communication flows regardless of the scale and complexity. As such, the model implicitly recognizes the need for integration between the subcomponents, the need for timely and effective communication links, and the importance of decision making that includes those associated with public response.

2.2 ORGANIZATIONAL ASPECTS OF WARNING

A recent report attempts to synthesize the process of evacuation decision making and to characterize the uncertainties encountered in previous emergency warning situations (Mileti et al., 1985). This study induces four general categories and nineteen specific uncertainties that constrain emergency decisions of public officials within emergency organizations. These categories are:

1. Problems of interpretation including difficulties in recognizing a hazardous event; recognizing the consequences or likelihood of an event; definition of the magnitude of the event; and failure to define an evacuation role, recognize relevant information, or define appropriate authority.

2. Problems of communication including who to notify, the ability to describe the hazard, the ability to communicate, and dealing with conflicting information.

3. Problems of misperceived impacts of a decision including panic, looting, or other adverse consequences; loss of job or other negative personal impacts; and economic costs of evacuating and liability.

4. Problems of exogenous influences including time availability, evacuation feasibility, prior experiences, planning, and outside pressures or expectations.

These constraints arise for a variety of underlying reasons. Management of emergencies and the processes involved in implementing warnings have been extensively documented in many case studies. These studies serve as a basis for understanding effective organizational responses to

emergency situations. Major relevant findings are briefly summarized in Appendix D. A summary of the concepts that relate to organizational effectiveness is provided in Table 1.

2.3 PUBLIC RESPONSE TO WARNINGS

Perry and Mushkatel (1984; 1986) describe an emergency decision-making model for natural and technological disasters. The protective action process is initiated upon receiving a message regarding a threat. A series of questions follows, and a negative response at any stage leads to inaction. At the first stage, the question is whether a threat really exists. Influencing the internal answer to this question are the presence of environmental cues and confirmation and perception of credibility of the warning source. If a threat does exist, it must be determined if the risk is personal. This evaluation is influenced by the content of the message received and previous experience. If the threat is real and personal, is protection possible? This answer is influenced by past experience and knowledge about the threat. The evaluation of protective action is followed by asking if protective action can be taken. This is shaped by timing, family context, and having a plan of action. The next question is whether action will significantly reduce the threat or consequences. The evaluation of effectiveness is thought to be influenced by past experience and sociocultural beliefs.

Finally, a recommended action is evaluated. If this action is in agreement with the assessment of the situation, the recommendation will likely be followed; if not, other choices are reviewed, while consideration is given to the actions of friends, kin, and neighbors. People at risk then proceed to take the action perceived to minimize the negative consequences.

A slightly different model of warning response has been advanced by Mileti and Sorensen (1987; in press). The model also suggests a staged set of processes over time, but it is less rigid in its structure. The warning response process is initiated when the warning is received. In many cases, receiving a warning is insufficient by itself for people to take action. The next stage is understanding the warning. Understanding involves the formation of mental images of the message content consistent with the threat situation. After understanding, people must come to believe that the warning is true and accurate. Next, they must personalize the message as being relevant to themselves. Finally, they must decide to take action and overcome constraints to taking that course of action. Throughout the process a variety of factors influence hearing, understanding, believing, personalizing, deciding, and behaving. These relate to the nature of the warning effort, the characteristics of the receiver, and the process of confirming the warning information. The relationship between such factors and warning responses has been extensively cataloged elsewhere and will not be repeated in depth in this report.

Table 1. A summary of concepts related to organizational effectiveness

Concept	Definition
	Organizational Relations
Role definition	Clearly defined responsibilities
Authority	Clearly defined powers and authority hierarchy
Territory	Clearly limited boundaries of authority
Priority setting	Understood mechanisms for setting priorities
Normative responsibilities	Similarity between normal and emergency
Legitimacy	Responsibilities are viewed as significant
Communications ability	Ease and clarity of access and information
Knowledge	Level of understanding about responsibilities
	Intra- and Inter-Organizational Flexibility
Formalization	Ability to deviate from written procedures
Adaptability	Ability to respond to new situations
Control	Ability to exercise and retain authority
	Interorganizational Network
Domain	Clearly defined division of responsibility
Dispute resolution	Mechanism for negotiating differences
Legitimacy of roles	Acceptance by other organizations
Resource adequacy	Sufficient resources to perform role
Autonomy	Ability to relinquish for good of system
Communications ability	High level of links between organizations
Authority	Network hierarchies are clearly established
Interaction clarity	Organizations know with whom to interact
Knowledge	Functioning of the system is understood

Consequently, this section only attempts to summarize some of the general research findings that can enhance the issuance of emergency warnings (Mileti and Sorensen, in press; Sorensen, 1984; 1982). In addition to the way in which a warning is issued, a variety of social and psychological factors influence the ways in which warnings are interpreted (Sims and Baumann, 1972; Mileti, 1975). Warnings are also supported by public education and information programs.

Ten factors have been documented as being important to the issuance of an effective warning. The first factor is the source of the information. Emergency public information or warnings that are credible and reliable to the people receiving them are more likely to stimulate evacuation. People have different views about who is credible and who is not, and any one source will not be perceived as credible by an entire population. A warning message that contains endorsements by a mixture of scientists, organizations, and officials is more likely to be considered credible.

Second, a warning message is more effective if it is consistent in the information given and the tone used to convey the message. Inconsistency in the tone or information in a message creates confusion and uncertainty among recipients (Segaloff, 1961). Also, it is important that the message be consistent in the way it conveys information about the level of risk. For example, a message stating that something bad is happening but there is no cause for concern is less effective than one that states how concerned people should be because of the severity of the situation.

Third, consistency among multiple warnings is also a determinant of understanding and belief. A study of the Rio Grande Flood (Clifford, 1956) found that inconsistent information caused confusion, and therefore, people were less likely to understand or believe that a flood was going to occur. Fritz (1957) reached the same conclusion in a study of warning responses in a wide range of disasters. Accuracy of the information also affects understanding and belief. For example, Mileti et al. (1975) states that past errors in disaster warnings can cause people to be less likely to believe subsequent warnings.

Fourth, clarity of the emergency information is important. An effective warning message is worded clearly and issued in simple language that can be easily understood; therefore, there is less chance that the public will misunderstand the message or ignore it.

Fifth, a message that conveys a high level of certainty about the events taking place and what people should do is more effective than a tentative one. Even if there is a low probability or an ambiguous situation, the messages can vary in their level of certainty (even about the ambiguity). Certainty determines the level of belief in a warning and affects decision making. In a study of response to an earthquake prediction, it was found that warnings became more believable as the probabilities attached to them became greater (Mileti et al., 1981). If warnings are certain, people are more likely to evacuate.

Sixth, the extent of the details included in a message influences evacuation decisions. Not knowing, or feeling that one has insufficient information, creates confusion, uncertainty, and anxiety. If messages contain insufficient information, the public's response is to fill the information void. This can promote rumors, uninformed misperceptions, and fears. The amount of information provided affects understanding, personalization, and decision making. A study of family response to hurricane and flood warnings conducted at the University of Minnesota found that general and vague warnings caused people not to take protective actions (Leik et al., 1981). In a study of response to the Mt. St. Helens's eruption, it was found that more detailed information led to higher levels of perceived risk, and therefore, more protective action was taken (Perry and Green, 1982b).

Seventh, messages containing clear statements of guidance regarding what people should do about the event being described and how much time they have in which to act are more effective than ones that do not provide specific instructions. Guidance is often necessary to encourage people to take proper action. A study of the Big Thompson Canyon Flood (Gruntfest, 1977) found that people who received warnings during the flood were not necessarily advised about what they should do. As a consequence, many who were warned attempted to drive out of the canyon and were killed.

Eighth, the frequency of public messages influences evacuation behavior. People often do not evacuate after hearing one warning. Frequent information is thought to reduce anxiety created by not knowing when one can confirm what is happening or where they can learn more details. In addition, frequent messages reduce the effect of misinformation and misperceptions. Frequency affects hearing, understanding, believing, and deciding, and is, thus, important at most stages of response. Numerous studies underscore the importance of repeated warnings as a condition for response.

Ninth is the specification of location in the message. Emergency warning information should state clearly the areas affected or potentially affected by the event. Identifying a location is important to the credibility and personalization of a warning. For example, Diggory (1956) found that the greater the proximity to a threatened area, the more likely a message will be believed. Other studies show that more location-specific messages lead to greater levels of personalized risk (Perry and Greene, 1983).

Tenth, the channel of information plays an important role in warning response. Effective warnings use a range of possible channels instead of a single channel. This helps in reaching as many people as possible in a short period of time. Moreover, some channels appear to be more effective than others. Personal communications are generally more effective in getting people to rapidly evacuate than media or sirens (Mileti et al., 1975; Gruntfest, 1977).

Effective public response is the chief goal of a public alert and notification system. The effectiveness of any given system cannot be

measured in a simple and easy manner. It is the results of a variety of factors including effective decisions, good communication among key authorities, effective dissemination of an alert to the public, and good emergency information. In the next section, the methodology for implementing these concepts with respect to emergency warnings for fixed-site chemical accidents is described.

3. METHODOLOGY

3.1 UNIT OF ANALYSIS

The unit of analysis for the study is the "community." A community is a social unit, not necessarily matching with a local political jurisdiction. Because the topic of interest is the community's response to a chemical emergency, specifically to alert and notify the public, the community is represented by the local political jurisdiction responsible for emergency alert, notification, and planning for chemical accidents.

If facilities are located in a sizeable city, this will likely be a municipal government or a combined city-county government. If the facility is located outside a major city, in a rural area or an unincorporated town, this will likely be the county government. Facilities in small towns could be served by either a county or city government with respect to the warning responsibility.

Thus, the mapping of the facility into the appropriate local jurisdiction is somewhat problematic, because no written data is maintained on the local organizational level responsible for alert and notification of the public on a systematic and comprehensive basis.

3.2 SAMPLING APPROACH

The U.S. Environmental Protection Agency (EPA) selected facilities that store or use 20 hazardous chemicals to represent current industry emergency planning, mitigation, prevention, and monitoring practices. The approach used to select communities to include in the study was to match a facility to the community with jurisdiction over that facility. The approach used to identify the appropriate community organization is based on the Federal Emergency Management Agency's (FEMA) national data base on local emergency response organizations. Their data base contains information on more than 3300 local emergency response organizations at the city, county, and combined city-county levels. It represents the best available data on local emergency responsibilities. The concept matched facilities to organizations in this data base at the city and county level. The city was used first, because it is, in most cases, the smaller unit (i.e., a single county may contain multiple municipalities, each with their own emergency response organizations). The match was then made at the county

level. When no matches were found for a facility, telephone calls were made to ascertain jurisdictional responsibilities.

3.3 SAMPLING FRAME

The EPA selected 525 chemical facilities to include in the study. The sampling was not random, but communities were selected as follows. First, the community in which each facility was located was matched to city-level emergency management agencies in FEMA's Hazard Identification Capability Assessment and Multi-Year Development Plan (HICAMYDP) data base. After all matches were made, counties in which the remaining facilities were located were matched to a county-level emergency planning organization in that same data base. When more than one facility was matched to a community or county, a single facility to use as the reference point was chosen. The following criteria were used for choosing facilities when more than one facility existed in a community.

1. Facilities known to be suspect, based on the returns of facility questionnaires, were eliminated.
2. Facilities that matched the name of the city identically were selected.
3. Facilities with the rarest chemical (out of the 14 chemicals with less than 100 facilities) were chosen.
4. Facilities with chlorine were selected.
5. Private companies were chosen.
6. Facility was randomly selected from among the pool of remaining facilities.

At this stage, 248 facility-community matches had been made. One hundred sixty-eight facilities were eliminated because they were not chosen when selecting a facility for a given city. Seventy facilities were dropped because they were not chosen at the county level. Thirty-nine facilities did not match the data base at the city or county level. Of these, appropriate local emergency management organizations were identified for 29 facilities. Ten facilities were never matched to a local planning organization. This resulted in a total sample size of 277 local emergency planning organizations that matched with a facility in the EPA survey of facilities. Thus, the final categories of facilities are as follows:

277	Sample communities
168	Eliminated because there were multiple facilities in a single city
70	Eliminated because there were multiple facilities in a county
10	Could not identify a responsible local emergency organization

Theoretically, some of the 70 facilities eliminated at the county level could be included if they were located in a municipality for which a local organization for alert/notification existed separate from the county. No attempt was made to identify such possibilities because of time constraints.

The screening question on the second page of the questionnaire contained a response that the facility existed but was located in another jurisdiction. In total, eight community organizations returned the questionnaire with another jurisdiction listed as being responsible. In all cases, the questionnaires were sent out to the replacement communities.

In several cases, the communities receiving questionnaires called to inform that the facility listed for the community did not exist, but they had other facilities with hazardous chemicals and wanted to complete the questionnaire. In such cases, they were instructed to fill out the questionnaire and to make a note of the name of the facility used as a reference point.

3.4 PROCEDURES USED FOR THE COLLECTION OF INFORMATION

The questionnaires were mailed to the chief or head of the local agency responsible for emergency planning in each local jurisdiction defined to be in the community sample. The majority of these were identified in FEMA's Hazard Identification Capability Assessment and Multi-Year Development Plan (HICAMYDP) for local governments' data base. Instructions were included to have the recipient of the package give it to the person in the jurisdiction or area who was in charge of emergency planning for the facility. Follow-up letters were sent to all communities that did not return the questionnaire. Four questionnaires were returned with incorrect addresses and were remailed at later dates.

3.5 RESPONSE RATES

It was estimated that with telephone follow-up calls, 60 to 70% of the communities receiving the questionnaire would respond. This report is based on instruments returned by March 1, 1988 and represents responses from 59% of the sample, and 49% from completed questionnaires. The other 10% were returned with the completion of the screening question indicating that the facility did not exist in the community. If the response pattern to the facility and community questionnaire is independent, an expected matched pair response of between 33 and 39% of the communities was predicted to be achieved initially. Based on the response rates achieved, about 14% of the communities would match a facility assuming random relations in the return rates. These data represent a 16% matching between the communities (N = 44) and the facilities surveys. Communities included in the study are listed in Appendix B by size and location.

3.6 QUESTIONNAIRE DESIGN

The questions are derived from previous empirical studies of emergency warning and alert systems for other hazards. Data concerning the community's ability to provide an alert are developed from a systems model of the emergency alert process (Sorensen and Mileti, 1987). The model specifies the general tasks, decisions, and information flows that define an emergency alert system. Questions in this survey measure each major element of the model.

Data on alert system effectiveness are derived from a review of characteristics associated with an effective emergency organization (Mileti and Sorensen, 1987). The survey measures the key organizational factors that previous research indicates are important in providing an effective alert.

Based on this approach, the questionnaire collects data in ten topical areas. These areas include emergency resources in the community, responsibilities to provide an alert, communications technologies, alert decision-making procedures, provision of public information, characteristics of the population at risk from the facility, warning technologies, the timing and contents of an alert, and the coordination of emergency planning.