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Review of Public Alert Systems for Emergencies at Fixed Chemical Facilities

John H. Sorensen
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Energy Division

REVIEW OF PUBLIC ALERT SYSTEMS FOR EMERGENCIES AT FIXED CHEMICAL FACILITIES

John H. Sorensen
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William F. Clevenger

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REVIEW OF PUBLIC ALERT SYSTEMS FOR EMERGENCIES AT FIXED CHEMICAL FACILITIES

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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

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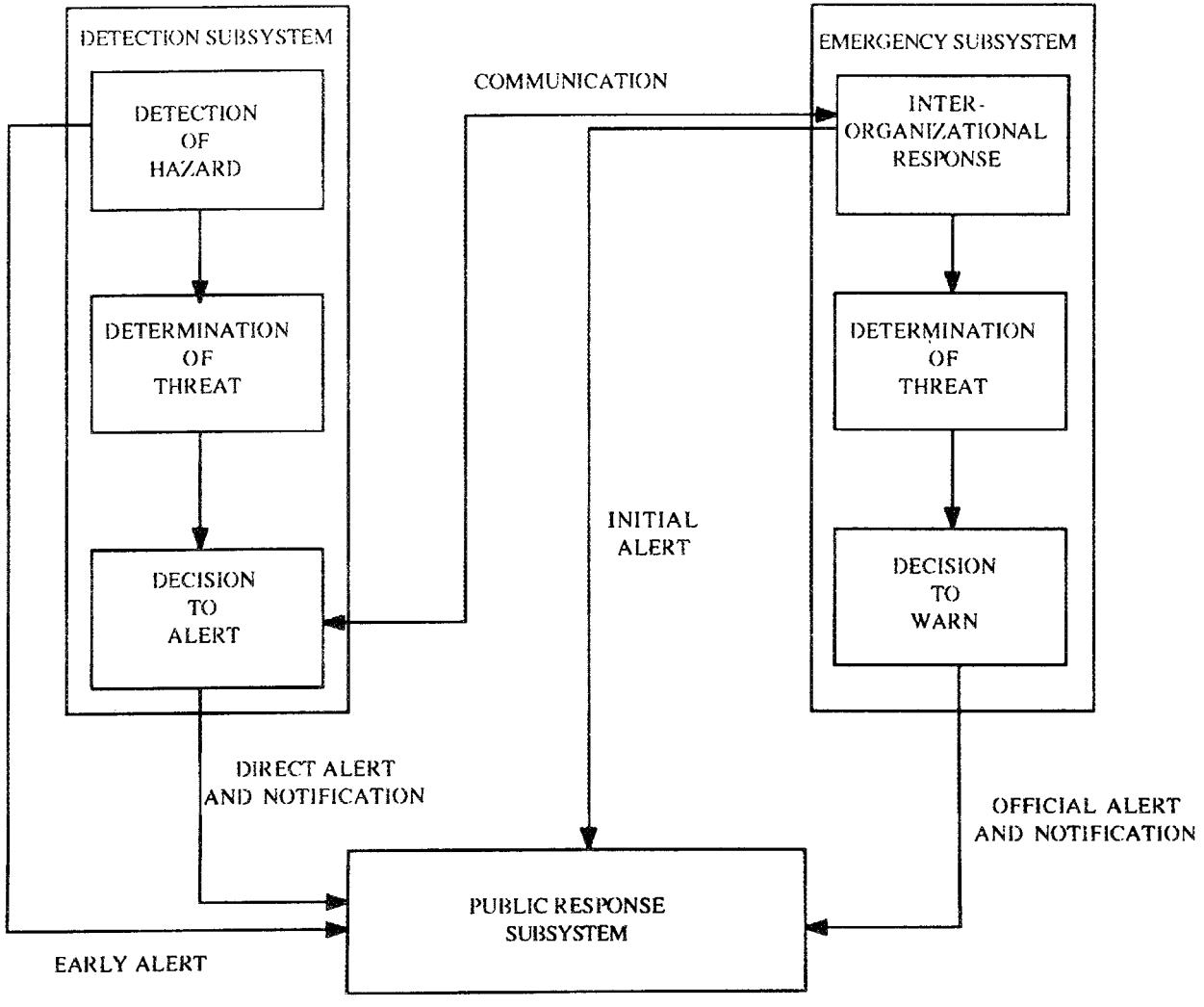

Fig. 1. A general model of key decision points and communication links in the warning process.

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.

4. FINDINGS

4.1 WHAT IS THE MAGNITUDE AND NATURE OF THE PUBLIC ALERT FUNCTION?

The public alert functions differ with respect to the numbers and types of human populations exposed to the risk. The number of households in an area, the population distribution, and the population density are relevant aspects of the warning problem.

A second relevant characteristic is population fluctuations. These can occur on a diurnal cycle; for example, a large number of commuters may be present during the day, but not at night. Conversely, suburban areas may have their peak populations at night. Weekly fluctuations may occur on certain days; for example, a recreation area that is crowded on weekends may not be crowded on week days. Finally, seasonal variation can be significant; waterfront areas may have a peak summer population but a much smaller winter population.

A third type of population characteristic involves special population subgroups. Institutional populations include people in schools, hospitals, correctional facilities, nursing homes, and other facilities in which people cannot fully care for themselves. Special warning considerations are required because it takes more time to respond to an emergency.

4.1.1 Residential Populations

The chemical facilities are located in fairly densely populated areas. An average of about 4400 people reside within a 1-mile radius of the facilities. In one case, 35,000 people are estimated to live within 1 mile. On average, the population density is about 1370 people/sq. mile assuming a uniform distribution.

Within 5 miles of the facilities, the average population is 42,600, with an average density of 550 people/sq. mile. The maximum population within 5 miles of a facility is estimated at 600,000. In several cases, however, the population within 5 miles is close to zero. Overall, the population density within 1 mile of the plant is much greater than that within 5 miles.

4.1.2 Fluctuating Population

Three types of population fluctuations were examined: diurnal, weekly, and seasonal. Diurnal population fluctuations are reported at roughly one-half of the sites. Weekly population fluctuations are more uncommon, occurring in 29% of the communities surveyed. Seasonal population fluctuations are reported in only 15% of the communities.

4.1.3 Institutional Populations

About 83% of the communities have institutionalized populations within 5 miles of the facilities. Several of these have facilities in numbers sufficiently large that respondents would report that there are many but not report the actual number; others may have only a few. Schools are the most common facility (64% of the communities) reported, followed by hospitals and nursing homes (41 and 45%, respectively). Twenty-five percent of the communities report having prisons or jails. All such institutional facilities require special and rapid warning consideration to give them the extra time needed to respond.

In 10% of the communities, a college or university is located within 5 miles of the facilities. Often these colleges and universities have large populations of students; therefore, they present different warning problems in that their populations are often dispersed over a number of buildings and are in constant movement.

4.1.4 Land Use

Land use is important in evaluating warning systems because it reflects the area in which different types of systems are best suited. Within 1 mile of the facilities, on average, about 61% of the land is estimated to be occupied by people, and 29% of the 61% is in residential use. Within 5 miles, that amount increases to 65%, with the percentage in residential use increasing to 39%. This represents an area of about

2 sq. miles that requires serious warning consideration and an additional 51 sq. miles within the 1- to 5-mile radius that requires warning consideration.

4.2 HOW WILL FACILITIES NOTIFY COMMUNITY OFFICIALS?

The link between the chemical facility and the people in the community usually is not direct. Warning decisions usually are made by city or county officials. The initial step of a warning is to notify the appropriate community officials or point of contact. This section presents analysis of how this is done and whether the process is effective.

4.2.1 Type of Equipment

Communities expect facilities to notify them in a number of different ways. The primary channel is by commercial telephone. Sixty-six percent of the communities cited telephone systems as the primary link. Approximately one-third of the communities stated that radios would also be used. This is not unexpected; these represent the most common forms of commmunication in general as well as in emergencies.

Both telephone and radio are not viewed by experts as highly reliable forms of communication. Telephones may fail (sometimes from the same event that caused the chemical accident) or may be busy. Radios often operate at different frequencies, are found inoperable, or are difficult to use because of heavy traffic on the appropriate frequency.

Some communication systems are designed to overcome such problems. These include dedicated telephone lines (a separate line not linked with commercial traffic), 911 telephone systems, dedicated radios, pagers, and special alarm systems. These are not commonly used in the communities studied, at least between the facilities within those communities selected as reference points. Dedicated telephones were cited in 5%; dedicated radios were found in 4%, pagers in 2%, and alarm systems in 4%. Only 3% judged that they would use the 911 emergency system to receive an alert despite the fact that one or more of the communities have 911 systems in their Emergency Operations Center (EOC).

In addition, some locations relied on less sophisticated or more passive means of alerting. These included using a messenger (3%) and relying on sirens (7%) or loudspeakers (7%). Such forms of communication are not very reliable.

It should be noted that more than one primary link existed between facilities and communities. On average, a community specified 1.5 primary channels to the facility. This means that at best, 50% of the cases rely on a single means of communication.

The availability of backup channels was mentioned by fewer communities. About 30% of the sample claimed to have some backup capabilities. Backup channels were varied; 15% cited two-way radios and only 5% cited either a dedicated backup or pager.

The channel of communications between the facility and community officials was provided in about 85% of the facility questionnaires. Given the fact that it was not asked for in the facility questionnaires, the responses are fairly consistent with the community. The major link is commercial telephone (43%) followed by a 911 emergency telephone (13%). In total, 20% reported that they use dedicated systems including telephone (10%), radio (6%), or alarms (4%). Some relied on sirens sounding at the facility (4%) or messengers (3%). No use of pagers or tone-alert radios was reported.

Overall, the findings are clear. The communication link between facilities and communities is not highly dependable or reliable. The main links are those that are frequently the cause of warning failures. Backup equipment is not adequate in many cases. This is not to say that failure is certain, but that state-of-the-art communications equipment exists in relatively few situations.

4.2.2 Linkages From the Facility Perspective: Do the Facilities Know Whom to Contact?

From the facility perspective, the major point of contact in the community is with an organization. Sixty percent of the facilities specified an organization or multiple organizations as the point of contact in the community. Roughly one-fourth (24%) of the facilities did not identify a contact point in the community with respect to name, position, and organization. Of these, 7% designated a contact point by some other means. The remaining facilities identified the contact by position only (5%); by position and organization (9%); or by name, position, and organization (2%). In 39% of the cases, only a single contact point was reported. In another 39%, multiple contact points were indicated.

Most of the facilities had assigned a position or person to be responsible for making the decision to notify community officials (93%). One-half of the facilities had specifically designated a backup position (50%), although 40% of the sample had more than one person assigned with this responsibility. Eighty-five percent indicated that someone was assigned with the responsibility during nonbusiness hours. In many cases (49%), this was the same person or persons with primary or backup responsibility. In others (36%), a different person had that responsibility.

4.3 HOW RELIABLE IS THE COMMUNICATION PROCESS?

In the previous section, the physical links between the facilities and the communities were examined as were the procedures established by the facility. In this section, the communications process from a

community perspective is examined. First, the aspect of interaction clarity is examined. Interaction clarity refers to the understanding an organization has about the person in other organizations with whom they will communicate. Second, whether there are vulnerable times of the day and week in the communications link is examined. Third, the degree to which procedures have been established to describe the communication process is examined. Finally, the information needed by communities to make warning decisions is examined.

4.3.1 Clarity of Interactions

Warning systems are more effective when it is known who will issue the alert and who will receive it. In this case, it is more precisely defined as who, at the facility, will alert officials and who, at the community, will receive that alert. Warning systems are also more effective if redundancy in this function is designed into the system. Thus, it is also important to know who will contact whom when or if the primary link breaks down.

First, consider the community's knowledge (measured by the identification of the name and position of people responsible for sending and receiving emergency notifications) about the reference facility's alert process. About 50% of the community officials identified the name and position of the person at the facility who is responsible for the alert. Another 18% of the community officials identified the position but not the name. Twenty-five percent of the sample could not identify either. Ideally every community would know at least the position of the person at the facility responsible for alerting them.

One would expect a poorer knowledge of backup communicators. Such is the case with 38% not knowing the name and/or position of the backup at the facility. Twenty-six percent of the community officials identified the person by name and position and another 28% by position only. This suggests only a moderate level of knowledge about interactions. This is a conservative stance, because as responders had the opportunity to retrieve the information from a plan or to call the facility and ask (as some did).

Even more important from the community's perspective is knowing who will receive the alert. Replication of the same inquiry revealed that 51% of the community officials identified the name and position of the person who would receive the alert. Another 39% knew the position that would receive the alert. Only 10% of the community officials did not identify the name and/or position, and 2% responded with unknown. As expected, knowledge of the backup decreased. Eighty-two percent identified the name or position of a backup. Those not identifying at least the name and position rose to 16%.

This suggests that the clarity of interaction is much higher within the communities than between communities and external organizations. Since communities act as the initial "receiver," it is important to examine the view of the sender.

In comparison to the community data, facilities expressed a similar level of knowledge about whom to contact in the communities as did communities regarding knowledge about who at the facility would contact them. The communities were more specific, however, in providing names or positions of the contact person. This may be more attributable to the more specific nature of the question posed to the communities than a lack of knowledge by the facilities.

Finally, the ongoing communications process is examined. This is important because emergencies are dynamic events. New information may affect the warning decision or change the content of warnings. Hence, it is important that organizations maintain communications. The effectiveness of this is determined by the reliability of communications equipment and the use of established contact points between organizations. Seventy-nine percent of the community officials identified the person in the community responsible for ongoing communications with the facility by name and/or position; 21% did not do so.

Overall, a high percentage of communities has established a point of communications within the community. This will help promote effective communications in an emergency. A lower percentage knows who will contact them from the facility. The smaller percent seems unsure of communications, has a greater potential for not receiving an alert from the facility, or a greater possibility of miscommunicating information when contacted.

4.3.2 Vulnerable Times

An emergency can occur at any time. Most larger urban areas maintain a point of contact on a similar time frame; other communities do not. To ascertain the extent to which communities could not be contacted, community officials identified the times during which it would be difficult for the facility to alert them. The lack of a 24-hour contact could delay a timely public alert.

The vast majority of communities maintain a 24-hour communications capability. (This is not to infer that the communications will be made to the contact point.) Eighty-eight percent indicated no potential vulnerabilities. Of those who did indicate problems, 8% expressed that they were vulnerable to missed alerts during nights; 4% during weekends; and 1% during evenings, nights, and weekends.

Overall, if the right person is called, most communities can be notified on a 24-hour basis. For a few, however, delays can occur while the community officials are being contacted if an emergency occurs at an off-hour.

4.3.3 How Well Established are Communication Procedures?

Once a community's point of contact receives an alert, it sets into motion, in many cases, a notification process within the community. The person receiving the notification seldom has the authority to issue a warning to the public. The ability to provide an effective and timely warning will be based on the efficiency of the community's response to the initial notification.

A major factor that determines the efficiency of the process is knowledge of what to do following the alert. Such knowledge may be reflected by a well-articulated description of the steps to be taken or by having a standard operating procedure to follow. Unclear knowledge or, even worse, no knowledge of what to do will delay or impede an effective warning.

All of the communities except 4% described the procedure they would follow upon receiving an alert. The remaining 96% were coded to indicate whether the procedure was clearly specified or in a Standard Operating Procedure (SOP) or whether it was described in vague generalities. Examples of a vague procedure would be "we would contact someone at city hall," or "we would send someone to see what was going on." An example of a clear procedure would be "we would call people on our notification list or backups in the order specified and activate the EOC where these people would gather to assess the situation." Of the 96%, about one-half were judged to have clear procedures and one-half had vague procedures. Because 65% of the communities indicated they had a written warning plan or procedure (although many did not provide evidence of this), we can interpret this to mean that some of the communities may not fully understand the contents of the plan or were unable to communicate the contents properly. Both are potential communications problems in an emergency.

As was done for the communities, the nature of the facility's procedures for notifying communities about an emergency situation was examined. This was done for both the decision to notify the community and the physical process of communication. The data indicate that most of the facilities have rather vague procedures or no procedures for either of these tasks. Roughly one-third has clear or standard procedures for decision making and communications. Slightly more than one-half (56 and 53%, respectively) had vaguely defined procedures. The remaining facilities either did not report the procedures or reported that they had none.

4.3.4 What Information is Needed?

An alert from the facility needs to be accompanied by the "contents" of a warning notification. Public officials will need to know more than the fact that an emergency exists to make a timely warning decision. In addition, the warning to the public must contain the "who-what-when-where-why" regarding the situation, as well as other relevant information. Therefore, we asked the communities to specify the information they needed from the facility to make a warning decision.

The most common and frequently cited item of information needed by the community is the type(s) of chemical released or involved (79%). The next most frequently requested information is the size or amount of material released (57%) and the human health risk or danger (42%). Relatively few communities indicated a need for information on plume or release location (37%), speed of dispersion (24%), potential pathways (24%), or protective action recommendations (20%). Still fewer indicated facility response, what actions were being taken by the facility to control the event (13%), or whether community assistance was needed (13%). Many, however, expressed concerns in a general way (e.g., what happened?). On average, communities cited 3.7 items of information needed.

These results are revealing; nevertheless, they should be interpreted cautiously because it is difficult to ask respondents to envision a hypothetical chemical accident of a general nature and list their needs on a questionnaire. Respondents may have assumed that a general response subsumed all of the more specific items; however, the fact remains that many communities do not know the necessary information to request in an emergency. Assuming that the person in the response organization who does know the right questions to ask eventually takes over communication, a delay will have occurred in getting the essential facts.

In several communities, notification sheets have been prepared to help the receiver of the initial alert to request relevant data. In these cases, the communities requested most, if not all, of the information, and some of them added information contained in our specific categories. The notification sheets help to ensure timely receipt of relevant information and a written record of what is received. This, however, is not the case in most communities, although there is a continuum in the amount and type of information requested.

4.4 HOW RELIABLE IS THE COMMUNITY DECISION-MAKING PROCESS?

The next stage of the alert process is for the community to reach a decision on whether to issue a warning to the public. This may not be a single decision but a series of decisions regarding precautionary warnings, warnings to take protective actions, warnings that the situation is not hazardous, or an announcement that the emergency has ended. The most problematic warning is for people to evacuate, shelter, or take some other form of self- or group-protection. This section, examines the authority and role of issuing warnings, the length of time to do so, the types of protective actions that would be considered, and the procedures for making a decision.

4.4.1 Authority

The state holds the authority to issue emergency warnings to its citizens in the event of disasters. Most states delegate such authority to municipal and county governments. That delegation means that the

authority to issue a warning is typically assigned to an individual or group of individuals in local government.

In most communities, the person(s) with that authority is identifiable by either name and position (67%) or by position (30%). In 2% of the communities, the persons in authority was unknown.

In most communities, the person with authority is also the person with the assigned responsibility of issuing a warning (79%). In 7% of the communities, no one has been assigned specific responsibility. In 13%, that authority has been assigned to a person other than the one with legal authority.

If authority is unclear or not assigned, warnings can be delayed while such authority is established. In most cases, this does not appear to be problematic.

4.4.2 How Long Does It Take to Decide?

The length of time it takes to decide to issue a warning is variable, depending on a host of factors. Critical factors include the amount of time it takes to mobilize decision makers, the number of people involved in the decision, the time it takes to reach a decision, and the urgency of the situation. The last factor seems to be critical; emergency systems can accelerate the speed of operations when a severe crisis is apparent. Conversely, when time allows, decisions proceed at a slower pace.

One way to accelerate decision making in an urgent situation is to involve fewer decision makers. In a fast-moving release of chemicals, communities indicated the need for involvement of an average of two decision makers. In a slow-developing emergency, the number expanded to an average of five. In many cases, a fast-moving event required only one person to make a decision.

For a rough estimate of the time it takes to mobilize decision makers, communities were asked to estimate a minimum and a most likely mobilization time to assemble decision makers in both slow-moving and fast-moving events. Although the means are within ranges established in actual emergencies, the estimates do not provide highly valid time estimates; they provide an indication of the effect of urgency on the time of warning dissemination. People could be assembled in roughly one-third less time if the situation warranted. In addition, the minimum times were about 50% lower than the most likely.

Similar relationships are also observed about estimates of decision-making time; that is, once assembled, the amount of time it took to reach a decision to issue a warning.

Overall, the average time estimated to arrive at a warning decision under ideal conditions and a fast-moving event was 18.4 minutes. A most

likely estimate, reflecting conditions that would interfere with mobilizing and decision making, had a mean of 30 minutes. Those expand in slowly developing events. The estimates reflect that many communities are capable of making timely decisions, although timely decisions are not guaranteed even when the situation warrants.

4.4.3 What Actions Will be Recommended?

Protective actions are the range of actions that can be taken to reduce exposure to a hazard during an emergency. For chemical emergencies, the most often practiced action is evacuation. Another major option is sheltering in a structure, often with enhancements such as taped windows and doors or ventilation system alterations. Other protective actions, not usually considered as such, include respiratory protection, skin protection, positive pressure shelters, decontamination, antidotes, and prophylactic drugs.

Protective action recommendations are an important part of the notification procedure. The public expects guidance, not merely to be told about the danger. When more than one protective action is considered, delays may occur in the decision process. On the other hand, when only a single action is considered for all situations, that action may not be an effective means of protecting the public under all accident scenarios.

Communities were asked what protective actions they would consider for the general public and institutions in a chemical emergency. For the general public, a slight majority of communities recognized both evacuation and some type of sheltering (54%). Many communities considered only the single action of evacuation (32%) and, to a much lesser extent, shelter (4%). Ten percent of the communities have not developed, or are in the process of developing, protective action strategies.

A similar pattern emerges for institutional populations. Sheltering is considered the only option for institutions by a larger number of communities (11%) than for the general population. Evacuation as a sole strategy diminished in appeal but still remains significantly large (26%). Evacuation or sheltering is the most popular strategy, although many indicated a philosophy of shelter first and evacuation in extreme conditions.

Overall, the use of sheltering as a protective action strategy is not as widely perceived as a viable option when compared to evacuation. A large number of communities are geared to an evacuation-only philosophy; a lesser extent to a shelter-only policy. Such policies reduce the problems in decision making but may increase the threat to the public in an emergency.

4.4.4 How Well Established is the Process?

The need for a procedure for making public alert and notification decisions follows the same logic as for the initial notification response. Clearly understood procedures lead to more timely and effective decisions. Respondents were asked to describe the procedure. Again, their responses were coded as having no procedure, a vague procedure, or a clear procedure. An example of a vague procedure is "we would evaluate the situation." An example of a clear procedure is "the mayor would consult with the fire chief and the plant manager, and if the plant thought that a release would get off-site, we would issue a warning."

The results indicated that 32% of the communities have clear or standard procedures for making a warning decision. Only 5% did not describe a procedure. The remainder specified rather vague procedures. This is consistent with another finding that 39% said they had a written procedure or plan for making a warning decision.

The lack of written or at least clearly defined procedures in the majority of the communities can be interpreted as another constraint to effective and timely public alert. It is not a showstopper, but it increases the probability of a warning-system failure or a delay in issuing the alert.

4.5 HOW WILL THE PUBLIC BE NOTIFIED?

Providing emergency information to and notification of the public of a potential danger is the primary objective of public alert systems. Disseminating emergency alert and notification to the public in the event of warning is identified as the leading problem (QI-1) facing emergency managers in the communities; 44% mentioned some form of public alerting when asked to identify the "weakest link" in getting an alert to the public.

Because the emergency response problems differ for various population groups, the warning systems, and the warning requirements vary among different groups. People close to the facility, for example, within a mile, require prompt warning of emergencies, while prompt warning is less critical for people within 5 miles, even though rapid warning is still required. Institutional and transient populations face different warning problems, complicated by problematic mobility and susceptible populations in the case of the former, and unfamiliar, special, or extraordinary circumstances in the latter. Warning systems also have to account for the tremendous variation in the location of people at various times of the day and days of the week.

4.5.1 Warning Equipment

Warning technologies include the following types of equipment:

1. fixed sirens or other acoustic signals,
2. fixed loudspeakers or public address systems,
3. portable sirens or loudspeakers,
4. vehicles with audio capabilities,
5. aircraft with audio capabilities,
6. tone-alert radios or pagers,
7. commercial television and radio,
8. emergency broadcast stations,
9. cable television override systems,
10. commercial telephones,
11. telephone-based automated systems and,
12. interpersonal communications.

Such technologies can be subdivided into several categories including

1.	sirens:	including 1 and 2 above
2.	EBS/media:	such as 7, 8, 9, and 10 above
3.	route alert:	such as 3, 4, and 5 above
4.	door-to-door:	including 4 and 12
5.	special notification:	such as 6 and 11 above

4.5.2 Use of Warning Technologies

4.5.2.1 Populations Within 1 Mile

Communities most frequently indicate that portable sirens and loudspeakers (50%) and the emergency broadcast system (49%) are used to disseminate emergency warnings to people within 1 mile. Frequently, permanent sirens, television, and radio are used (43%). Of the remaining technologies, no system is used by more than one in four communities and only one (cable override) is mentioned by more than one in five. Technologies that are characterized by rapid warning and effective dissemination of both an alert and warning message, including tone-alert radios (13%) and telephone ring-down systems (2%), are used less frequently. Predominantly, the systems being used are either characterized by cumbersome dissemination of alert signals (such as route or door-to-door alerting [30%]), or they require a specific action on the part of the recipient (i.e., turning on the radio or television to receive the warning message). Most people living within 1 mile of a chemical facility could be less vulnerable to the consequences of a rapid onset chemical accident if the emergency and automatic warning systems were improved to provide more immediate alerts and messages.

Secondary warning systems for people within 1 mile include portable sirens or loudspeakers on vehicles (36%), television or radio (36%), cable override (24%), door-to-door alerts (49%), commercial telephones (24%),

and the Emergency Broadcasting System (EBS) (21%). In addition, airplanes or helicopters (16%) and two-way radios (13%) are also mentioned as part of the backup warning system.

4.5.2.2 Populations Within 1 to 5 Miles

The technologies most frequently used by communities to warn people within 5 miles of a facility are the EBS (53%) and television and radio (49%). Portable loudspeakers and sirens on vehicles are used by 43% of the communities. Of the remaining technologies, no other warning system is used by more than one in four communities. Cable override is used by about 22%. While immediate public alert is somewhat less critical, because of the additional time it takes for a plume to travel more than 1 mile, people in the 1- to 5-mile area still require rapid alert and notification of emergency situations and appropriate protective actions. Warning systems characterized by rapid dissemination and relatively effective warning message deliveries are again less frequently reported as part of the emergency warning systems in use. Tone-alert radio and telephone ring-down systems are reported 12 and 4% of the time, respectively.

Secondary warning technologies for people within 5 miles include portable sirens or loudspeakers on vehicles (44%), television or radio (34%), cable override (23%), commercial telephones (24%), the EBS (17%), and door-to-door alerts (50%). In addition, airplanes or helicopters (16%) and two-way radios (12%) are used as part of the backup warning system.

4.5.2.3 Institutional Populations Within 5 Miles

Institutional populations are most frequently warned by technologies primarily designed for general populations; television and radio (35%), the EBS (35%), and permanent fixed sirens (28%). Commercial telephones are used in 38% of the communities. Emergency warning systems that are most effective for institutional populations are reported less frequently. Tone-alert radios are used in 20% of the communities, and telephone ring-down systems are part of 10% of the existing systems. Direct contact by two-way radios and door-to-door alerts are used in the institutional warning systems 13 and 18%, respectively. The emergency warning systems for institutional populations are primarily the same as warning systems for the general population. Because of the special response characteristics associated with institutions, direct emergency warning systems dedicated to institutional problems would be more effective.

Secondary warning technologies for institutional populations within 5 miles are door-to-door alerts or personal warnings (42%), portable sirens or loudspeakers on vehicles (35%), television or radio (31%), the EBS (22%), cable override (20%), and commercial telephones (20%). In addition, airplanes or helicopters (13%) and two-way radios (13%) are part of the backup warning system for institutional populations within 5 miles of the facility.

4.5.2.4 Transient Populations

Warning systems for nonresident populations are least frequently reported by community emergency management officials. The most frequently used warning technologies are the same as the general public alerting and notification systems. Television and radio are the most frequently used warning mechanisms (37%), with portable sirens and loudspeakers (36%) and the EBS (35%) being reported frequently. No other warning technology is used by more than one in five communities, and only permanent sirens (23%) and cable override (10%) are reported by more respondents than one in ten. Tone-alert radios, fixed loudspeakers or public address systems, commercial telephones, two-way radios, and other systems are used by less than 5% of the communities.

Secondary warning technologies for transient populations are either portable sirens and loudspeakers on vehicles (27%) or door-to-door or personal alerting (27%). Television or radio (20%), the EBS (12%), cable override (11%), and commercial telephones (10%) are also used. In addition, airplanes or helicopters (10%) and two-way radios (5%) are mentioned as part of the backup warning system for transient populations.

4.5.3 Warning Systems

Warning systems can be further characterized as three basic types with the following subclassifications.

1. Enhanced systems use sirens and some form of specialized alerting such as tone-alert radios.

2. Siren-based systems rely on sirens for alert with use of media-based notification.

3. Ad hoc systems rely on media and the EBS and door-to-door or route alert.

Enhanced systems are capable of fast alert and fast notification for those with specialized alerting. Siren-based systems have the potential for fast alert (based on coverage) with notification being more problematic. Ad hoc systems require more time to implement and reach the public with a message.

The predominant method for warning people in close proximity to the chemical facilities is an ad hoc system (45%). Sixteen percent rely on route alerts or door-to-door notifications. Twenty-nine percent rely on the EBS or media warnings. Siren-based systems are used in 33% of the communities. Twelve percent use an advanced system involving both sirens and tone-alert radios.

All of these systems would be effective in an emergency with a 3- to 4-hour lead time or in supporting a precautionary response. In a rapid

moving event, however, the majority of systems (including siren-based systems) are likely to provide an effective warning.

In the 5-mile radius, a slightly greater reliance is placed on ad hoc systems, and a lesser reliance is placed on sirens or tone alerts. There is more time to alert the more distant populations, but the ability to issue quick alerts is similar to that in the 1-mile radius.

The use of tone-alert based systems and the as telephone increases for institutional populations; less reliance is placed on ad hoc or sirens. Nevertheless, conventional systems are used in about one-half of the communities, and tone alerts are used in 18% of the communities. Although institutions need special warnings to allow extra time to implement protective responses, many do not have that extra margin of safety. Twelve percent of the communities have no provisions to warn institutional populations.

Transients are largely ignored as a group requiring emergency warning. Eighteen percent of the communities have no system in place for warning such groups. The majority of communities rely on ad hoc or siren-based systems to warn transients.

4.5.4 Warning Time

The average time estimate for warning the general public within 1 mile of the facility is 30.7 minutes, but communities were unable to make such estimates 32% of the time. The basis for these estimates is predominantly (45%) comprised of professional judgment, which is typically comprised of a logical explanation of the process by which the public would be warned. The basis of the time estimates is not described 37% of the time. About one in five community officials reported basing the time estimates on drills, exercises, other "routine" emergency response (e.g., house fires), and previous disasters.

4.5.5 Source of Emergency Warning

Several sources of warning add credibility and believability to the warning message. Because the credibility of a warning message is crucial to public response, the identification of the source of the warning information is a critical element of the warning process. Emergency warnings are more likely to be effective when multiple sources are indicated and when local authorities, political as well as technical, are associated with the warning message.

The civil defense or emergency management official is the most frequently reported source of warning information (83%). Additional emergency management and public safety people reported as sources of emergency warnings include: the fire chief (74%), the police chief (60%), and the sheriff (46%). The most frequently mentioned manager or political official reported as a source of the warning is the mayor (53%). This is

followed closely by the chemical facility manager (47%), county executive (40%), the city or county manager (31%), and state officials (28%). Sources of warning information that would be considered technical experts include public health officials (27%), a scientist or engineer from the facility (22%), and government scientists or engineers (7%). An additional 3% reports that no one would be identified as the source of the information, and 10% reports other sources.

The people in charge of the emergency, at least in its initial phases, are well represented as sources of warning information. This tends to achieve "situation credibility"; that is, there is an element of understanding about the current situation. Local government officials are also represented, although less predominantly than emergency officials. Therefore, "credible authority" is not as developed as it should be. This type of local authority establishes who is in charge and determines why people should listen to an emergency warning. Technical experts are the most underrepresented source of warning information. These experts establish the "technical credibility" or public confidence in the warning message. Warning messages are likely to be most effective when all three sources of warning are firmly established.

About 20% of the communities responded that they would use a single authority as the warning source. Forty percent would attribute the warning to political or management personnel such as the mayor, facility manager, city and county executives, or state officials. At least one of each type of authority was reported by 36% of the communities in the survey.

While 12% of the respondents reported multiple people in each category of warning source credibility, there is a tendency to over-identify emergency managers and political or management positions as sources of warning and to underrepresent technical information sources. Emergency managers cannot issue emergency warnings under a simple "stimulus-response" model of public reaction and achieve effective emergency response. These three types of warning credibility (situation credibility, credible authority, and technical credibility) are established by specifically identifying these types of people as sources of emergency warning. Public response to an emergency warning can be significantly improved by (1) establishing warning message protocols that clearly identify warning sources and (2) establishing public confidence by enhancing situation and technical credibility and credible authority.

4.5.6 Warning Preparedness

Preparedness is partially represented by having plans and procedures and by "priming" the system with tests and public education. Preplanned messages are also a sign of preparedness.

Warning equipment is tested on a fairly routine basis, with most communities reporting such tests on a weekly (32%) or monthly (26%) basis. Some communities (13%) report testing of warning equipment and procedures

on a daily basis, but 19% report testing warning equipment and procedures less often than monthly. Ten percent of the communities reported no testing at all. Written protocols for communications with the general public through the EBS or the media have been prepared in 33% of the communities in the survey, and protocols for institutional facilities are available in less than one community in five (19.7%). Few communities have protocols for foreign-language populations.

Despite the fact that little evidence exists that public education makes a difference as to whether a warning system will function effectively, most agree that it contributes to an effective response. The majority of communities have either no public information program or a poorly developed one. Only 19% described a program with multiple activities. A single activity, the preparation of a brochure, was initiated by another 21%. Of the 40% who described a specific program, however, only 15% provided evidence that a program actually existed.

4.6 EMERGENCY PREPAREDNESS AND SARA, TITLE III

The overall emergency preparedness for chemical hazards is just beginning. Qualitatively, the single most frequently reported sentiment is that SARA, Title III, is characterized as a program that has just begun by taking the initial steps. The SARA, Title III, process is generally viewed by the communities as a source of hope for better emergency planning and management in the future.

4.6.1 Stage of Title III Planning

Most of the communities represented in our survey report that the Local Emergency Planning Committee (LEPC) is a county or parish entity (62%), 10% report that the LEPC is designated as a city, and 2% report it as a multicity entity. While 88% of the communities in the survey report that the membership has been appointed and 79% indicate that their community is represented, our impression is that many of these communities have met only a few times, and some have not met at all. Sixty-seven percent of the communities reported using information provided by the Chemical Manufacturers Association (Community Awareness/Emergency Response) (CAER) Program (1987), but 33% have not used this information.

4.6.2 Coordination

Coordination between emergency organizations may be characterized in terms of the amount and type of association. Conceptually, coordination is measured on a ranking system where "no contact at all" is the least associated and "initial or introductory contact," "development of emergency response plans together," "on-going coordination of emergency response effort," and "participating in exercises together" represent additional levels of coordination. Therefore, links between communities and other organizations reported as initial or introductory contact are

conceptually more coordinated than links characterized by no contact at all. Similarly, relationships characterized as "ongoing coordination" are more coordinated than the three previous ranks of coordination and less coordinated than participating in exercises together. In essence, each level of coordination presumes, or depends, on the previous levels of coordination.

4.6.2.1 The Chemical Facility

The communities report that their coordination with the reference chemical facility includes participating in exercises 50% of the time. Relationships with the reference facility are characterized as only initial or introductory contact by 28% of the communities, and 6% report no contact at all. Coordination is characterized as "ongoing" or comprised of the "development of plans" together by 17% of the community emergency officials in the survey. Most of the communities (80%) report that the facility has provided information describing the hazardous chemicals used at the facility. Many of these specifically report that the Materials Safety Data Sheets have been provided.

4.6.2.2 Other Local Agencies

The communities report that their coordination with other local agencies includes participating in exercises 67% of the time. Coordination is characterized as "ongoing" or comprised of the "development of plans" together by 18% of the community emergency officials in the survey. In addition, 65% of the communities participate in exercises with hospitals. Relationships with the hospitals are characterized as only initial or introductory contact by 12% of the communities, and 2% report no contact at all. Coordination with hospitals is characterized as "ongoing" or comprised of the "development of plans" together by 18% of the community emergency officials in the survey.

4.6.2.3 Other Communities

Forty-eight percent of the communities report that they participate in exercises with other communities. Relationships with other communities are characterized as only initial or introductory contact by 20% of the communities, and 6% report no contact at all. Coordination is characterized as "ongoing" or comprised of the "development of plans" by 27% of the communities.

4.6.2.4 The Media

A majority of the communities report that their exercises include the media (58%). Relationships with the media are characterized as only initial or introductory contact by 18% of the communities, and 7% report no contact at all. Coordination is characterized as "ongoing" or

comprised of the "development of plans" by 18% of the community emergency officials.

4.6.2.5 State Agencies -- Civil Defense (CD) and State Police

The communities report significant coordination with state civil defense (67%) and state police (52%) through exercises. Hence, state agencies are involved with local agencies in emergency exercises in more than one-half the communities. Relationships with state CD and police agencies are characterized as only initial or introductory contact by 10 and 17%, respectively, and 5 and 8%, respectively, report no contact at all. Coordination is characterized as "ongoing" or comprised of the "development of plans" by 17 and 20% for state CD and police, respectively.

4.6.2.6 Federal Agencies -- Federal Emergency Management Agency (FEMA and the Environmental Protection Agency (EPA)

The communities report more limited contact with federal authorities. Their coordination with FEMA and the EPA includes participating in exercises 34 and 15% of the time, respectively. Relationships with these two federal agencies are characterized as only initial or introductory contact by 24 and 38% of the communities, and 12 and 27% report no contact at all. Coordination is characterized as "ongoing" or comprised of the "development of plans" with FEMA and EPA by 30 and 17.1%, respectively.

The average number of exercises a community reports participating in is two, but 21.4% of the communities report not having participated in any emergency exercise in the past 2 years.

4.6.3 Facility/Community Interactions

From the facility perspective, the three major types of community organizations involved with chemical emergency alert and notification procedures are the local fire departments, local emergency planning or civil defense offices, and local law enforcement agencies. Facilities have varied levels of interaction with each of these three groups. The greatest interaction is with fire departments. About 45% of the facilities have participated in exercises with fire departments as compared to 34% for emergency planning and 31% for law enforcement departments. Another 25% of the facilities work with fire departments on an ongoing basis. Fewer do so with emergency planners (22%) or police (21%). The majority of those who have participated in exercises with such groups reported having either one or two such events in the past 2 years.

All of the facilities indicated that they had at least some coordination with local fire departments, although 7% reported that they did not have a fire department. Ten percent of the facilities reported no

coordination with local emergency planning agencies, and another 11% reported no such agency in their locations.

4.7 HOW DO EXISTING PRACTICES DIFFER FROM STATE-OF-THE-ART PRACTICES?

It is difficult to define precisely what constitutes state-of-the-art public alert and notification systems because state-of-the-art for one situation is not for another. For example, a facility storing phosgene that is located in very close proximity to a school and densely populated areas will have a different state-of-the-art system than a facility that uses acrylonitrile that is located in a sparsely populated or rural area. A second reason is that critical elements of a state-of-the-art warning system are difficult to assess in a deterministic manner. A community could possess the latest and best electronic sirens or a computer-driven telephone calling system, but unless they receive prompt notification from the facility, such equipment may be useless. The quality of that link, however, can be assessed only in qualitative or relative terms. Nevertheless, we can present additional information that helps to evaluate the status and effectiveness of public alert and notification systems for chemical hazards in the United States, and to compare them to state-of-the-art (when the state-of-the-art is defined as the most advanced technologies and management practices currently available).

4.7.1 Weak Links

4.7.1.1 The Community Perspective

One way of assessing warning systems is to have communities make evaluations of the public alert and notification systems for the reference facilities. Community respondents identified the weakest links in issuing a timely and effective warning as a means of focusing on areas in the systems that are most prone to failure. Only 2% of the communities indicated there were no weak links in the system. The other 98% identified a number of different problem areas. The most frequent concern was for the ability to disseminate a timely warning to the public with the existing public alert and notification systems. Forty-four percent of the communities indicated that they lacked the warning technology to reach the public effectively. Many of these communities rely on ad hoc warning procedures such as the combination of door-to-door alerts, portable loudspeakers and sirens, and activation of media-based warnings.

The second most frequently cited weakness in the systems involves communications with the facility. One-fourth of the communities felt that obtaining timely information from the facility was a major problem in the warning system. In contrast, 5% expressed concern for the communication link with the facility, and 7% felt the problem was the lack of cooperation from the facility in establishing plans and procedures. The third weakest link was the communication process within the community (11%). These included finding decision makers, getting information from the point of contact, or poor communications equipment. Another 8% felt that the

lack of training or poor planning was the chief obstacle to a good warning.

Warning systems involve the public as well. Ten percent of the communities said that public apathy or poor public response was a weak link. This helps illustrate the need for public education and information programs.

4.7.1.2 The Facility Perspective

Facilities agreed with communities that the weakest link in the warning system was a lack of the means to disseminate both an alert and a notification to the population surrounding the facility. This was cited as the weak link by 31% of the facilities. Furthermore, many facilities clarified the problem by citing the population characteristics as a reason that warning dissemination was difficult (15%). Difficulties were attributed to both a dense population or a sparse population spread out over the area surrounding the facility. Facilities tended to agree with communities that lack of public knowledge was another weak link (13%).

Facilities differed from communities in their stances regarding communication problems. While a few from both facilities and communities (facilities = 8%; communities = 5%) agreed that the communication channel between facilities and community was a weak link, the stances on internal communication problems differed greatly. Although 24% of the communities felt that getting timely information from the facilities was a weak link, only 4% of the facilities defined internal decision making and communication as a major constraint. The same pattern holds for internal communication within the community. Eleven percent of the communities expressed problems with their own communication. Only 1% of the facilities saw community communications as a problem, and a few facilities saw community cooperation as a problem (2%).

On other issues that were examined, the views of communities and facilities were quite similar, but less than 10% of the sample responded. The subjects included lack of planning, lack of training, warning special populations, and the feasibility of protective actions. One major difference between communities and facilities is the attitude that no weak links exist. Twenty percent of the facilities saw no weak links in the public alert and notification system. This view was expressed by only 2% of the communities. Perhaps this reflects the industry view that a problem does not exist, which contrasts with the community view that ways of improving emergency preparedness always exist. Overall, the facilities were far more optimistic than the communities that an effective alert would be given should an emergency occur.

Overall the self-evaluations reinforce some earlier conclusions. Timely and effective warnings are constrained by poor communication links between the facilities and communities and within communities. Finally, the warning system must acknowledge the public needs to play an active rather than a passive role in maintaining the system.

4.7.2 How do the Facilities Compare with Others?

Because the facilities selected for study do not represent a random sample of all facilities in the country, the ability to generalize is limited. We cannot ascertain whether the communities are representative of all communities with hazardous chemical facilities, but we can determine the advantages of planning for the reference facilities compared to those for other facilities in these communities.

The vast majority (94%) of the communities contain other facilities that store or use hazardous chemicals. On average, the communities estimated that 142 other facilities exist that require emergency planning. The median number of facilities was 20. When asked about the emergency planning efforts of the facilities being used as the reference point for comparison to others, most rated them as better than average. Twenty percent thought they were better, and an equal number felt they were somewhat better. Forty percent of the communities evaluated them as average and only 7% rated the facilities as poorer than average.

Community respondents also compared the communities' ability to issue warnings to the public in the vicinity of the reference facilities with other facilities in the community. The pattern shifted somewhat, moving from above average to more neutral. About 62% responded "about the same as for others." The number above average was 25%, and only 6% fell below average.

These patterns of response may be attributed to two factors. First, the facilities selected tended to be large facilities that would be more active in emergency planning than smaller companies. Hence, the quality of their emergency planning should be rated higher than average. Second, the quality of emergency planning at the facility is only one factor in the communities' ability to issue a warning; therefore, the facilities represent a more typical warning situation for the communities. Overall, the warning systems for the reference facilities must be viewed as being better than normal for all facilities in these communities, although the degree to which they are better cannot be precisely quantified.

4.7.3 What can be Done to Improve the State-of-the-Art?

State-of-the-art public alert and notification systems can be improved in two fundamental ways. First, the dissemination of existing technology and resources that would enable better planning and emergency response can be enhanced. Second, the existing technology and knowledge that defines the state-of-the-art can be advanced. To understand what is important from the viewpoints of the communities, they were asked to rank areas that they felt additional resources or equipment and improvements in knowledge and technology would improve their chemical emergency planning programs.

Consistent with our earlier findings, acquiring improved public alert and warning equipment was, on the average, the primary community need.

The second- and third-rated needs also related to warning systems. These needs were new communications equipment and computer-based emergency management systems. Contrary to our expectations, funds for planning and training were lower on the lists of needs.

A similar pattern is found for new knowledge and technology. The two top priorities were improved public alert and warning technologies and improved communication technologies. These were followed by improved knowledge on protective action effectiveness and improved training programs. The area least in need of improvement was improved planning guides.

4.7.4 The Effectiveness of Public Alert and Notification Systems

The analysis has demonstrated some gaps between existing practices and state-of-the-art and some constraints that will impede timely dissemination of alerts. To further understand the magnitude of these problems, communities were asked for their overall assessment of capabilities to provide a timely warning to the public surrounding the reference facilities. The measure is, of course, relative; it provides no absolute indicator of the probability of successful warnings. It can, however, help to calibrate the interpretations of other measures of effectiveness. The majority of the communities expressed some level of certainty that an effective warning would be made in an emergency. Twenty-six percent said it was highly certain, and 49% stated it was somewhat certain. Twenty-five percent, however, cast some doubts that an effective warning would be made in their communities.

Overall, this can be interpreted as being consistent with the pattern of results from the rest of the study. The quality of the alert and notification systems ranges from somewhat poor to outstanding. The notion of variability is reflected in the responses to the question of the effectiveness of public alert and notification systems. The next section develops a more systematic method to appraise the overall quality of these systems.

5. PUBLIC RESPONSE TO WARNINGS

Eliciting effective public response is the objective of the warning process. Hence, the public, as receiver of the warning message, comprises a fundamental element of the warning process. The public component of the warning process begins when information concerning a potential threat reaches the general public, and it ends after the threat dissipates. Public officials may view the public warning process more bureaucratically; demarking the public component with the decision to warn at one end and the public receipt of the "all clear" signal at the other. This section discusses the receipt of a warning by the public, the response to warnings of chemical hazard, and the overall effectiveness of warning

systems. The warning process is briefly discussed from the public's perspective.

5.1 THE WARNING PROCESS

Warning the public of the threat of an impending chemical hazard encompasses two steps: to make them aware of an abnormal set of circumstances characterized by an elevated threat and to provide information to elicit actions to minimize the dangers associated with the threat. The former is referred to as the alerting function; the latter constitutes the notification function, which involves alerting the public that a hazard is imminent. Notification involves communicating the warning message so as to prompt mitigative response to the hazard. The central focus of alerting issues involves the technical ability to make people aware of the threat, and the primary notification issues focus on the public's interpretation of the warning message.

Warning messages are passed along a series of pathways that can change their associated meaning. These pathways of warning communication involve cognitive functions as well as social structural considerations. The cognitive functions include the belief in the warning message, the personalization of the associated threat, the credibility of the source of warning, and the perception of the content. The social structural considerations involve the social context of the hazard, including the interactions with others in the social network, prior experience, extant social and physical environments, and existing conditions that interact with and influence the warning message. The response to an emergency warning is based on the degree of assessed hazard or danger, the threat, and the public's experience as placed in the social context. Therefore, the decision to accept, ignore, disseminate, challenge, or confirm the emergency warning message (Baker, 1979) rests on this social context.

Psychologically, emergency warnings that result in the recognition of threat, create discomfort and uncertainty of the impending event. The emergency warning process involves both the message and the characteristics of the receiver. Having received the message, it is evaluated in terms of certainty and whether the anticipated severity, timing, and location of impact are ambiguous. The message is personalized in terms of relevance; for example, "Is the threat likely to effect me?" The resulting relevance of the warning message is determined in the context of prior disaster experience, relative proximity, credibility of the source of warning, interpretation, and discussion with others. Hence the warning message is processed in the context of the social network.

Janis (1958) describes effective warning messages as those requiring a delicate balance between fear-arousing and fear-reducing statements. By describing the impending danger in sufficient detail, a vivid mental image of the impending crisis is evoked. This fear-arousing part of warning messages reduces the possibility of surprise, and invokes response. The realistic presentation of the mitigating factors of the potentially threatening situation provides information regarding both the actions of

authorities and those of individuals. This fear-reducing component of the warning message provides the foundation for adaptive response. "The fear-arousing content of the warning message alerts the public to the potential for harm, while the fear-reducing statements consist of notification of appropriate mitigation action" (Rogers and Nehnevajsa, 1987: p. 358).

5.2 DESCRIPTION OF EVENTS

A relatively weak set of empirical data exists on human behavior in chemical accidents. At the organizational level, about 20 case studies document the response of public officials to an emergency (Quarantelli, 1981; 1983). Some of these studies include the warning process.

At the individual level, five events have been researched in which warning responses were documented. These include a nitric acid spill in Denver, Colorado (Perry and Mushkatel, 1986), a railcar derailment involving propane in Mt. Vernon, Washington (Perry and Mushkatel, 1984; 1986), the Mississauga, Ontario, accident involving chlorine (Burton et al., 1981), and two recent train derailments in Pennsylvania. These events are summarized in Table 2.

5.2.1 Mississauga Chlorine Gas Release

On Saturday, November 10, 1979, at 11:54 p.m., a series of tank cars including one car filled with 90 tons of chlorine, four cars filled with caustic soda, a string of cars containing propane, and three cars containing styrene derailed in Mississauga, Ontario, Canada. As the result of the derailment "... the propane cars were either ruptured or damaged, with their contents flowing off or exploding" (Burton et al., 1981:2-11). The chlorine car was punctured by the car following it, and the content of the cars containing styrene and caustic soda poured onto the tracks.

A number of local- and municipal-level emergency response agencies responded, including regional police, fire and ambulance services. Police units in the area at the time of the accident were alerted by the light from the explosions, and three or four police units converged on the scene. The first police units to arrive on the scene reported the accident to the radio dispatch. A constable and a detective sergeant arrived on the scene within several minutes. Within three minutes, the people on-the-scene requested additional personnel, but alerting fire personnel was not necessary because of the high visibility and recurring shock waves caused by repeated explosions. Ambulance services were also alerted by the explosions, with four ambulances being dispatched to the scene within four minutes of the accident. Ambulance service personnel stationed themselves strategically around the area as no initial injuries where reported. The repeated explosions also alerted the general public; however, many converged on the area until emergency workers cordoned off the area within 600 meters.

Table 2. Public response to emergency warning summary

	Pittsburgh	Confluence	Mississaug[a]	Mt. Vernon	Denver
Population at risk	16,000-22,000	986	3500	3750	4900
Percent warned	73.2	90.5	99	82	96
How warned	Ad hoc	Ad hoc	Ad hoc	Ad hoc	Ad hoc
Available warning time	NA[b]	NA[b]	2 h[c]	2.5 h[c]	2.5 h[c]
Percent evaluated evaluated	40	85	98	67	82
Hazard description	Phosphorous oxychloride	Hazardous material residues	Chlorine	Propane	Nitric acid
Nature of hazard	Release/fire	Precautionary	Release/fire/ explosions	Precautionary	Spill/small fire
Day of event	Apr. 11, 1987 Saturday	May 6, 1987 Wednesday	Nov. 10, 1979 Saturday	Apr. 22, 1981 Wednesday	Apr. 3, 1983 Sunday
Time of event	12:25 p.m.	4:20 a.m.	11:54 p.m.	7:45 p.m.	5:30 p.m.
Time of warning	12:25 p.m.	4:20 a.m.	7:47 a.m.	10:00 a.m.	5:30 p.m.

[a]First area to be evacuated.

[b]Not available.

[c]Time to warn the total percent warned above.

Because the location of the chlorine tank car had not been determined; a visual check taking 20 minutes was made of each tank car. The search revealed that the chlorine car probably was engulfed in the jumble of cars at the center of the derailed section of the train. After consulting with railroad officials, fire department representatives, the procedural representative, and the advisor from Ashland Chemicals, emergency officials decided to evacuate the downwind areas (i.e., areas south and west of the site). At 1:47 a.m., nearly 2 hours after the accident, the first official evacuation was ordered. Police were instructed to go door-to-door and tell residents that dangerous gases were on the train and advise them to leave the area. Before the emergency was over (including the staged evacuation and re-entry), approximately 250,000 people were forced to evacuate their homes.

On Tuesday afternoon, re-entry began with those farthest from the accident site when erroneous media messages led to massive traffic jams. Final re-entry for those in close proximity to the accident site began on Friday afternoon after a lengthy control-group meeting. By 4:00 p.m., 18 tons of chlorine had been removed, leaving only 4000 to 5000 gallons. This led to a consensus decision by all experts that the remaining evacuees could safely return to their homes. To avoid concentration of potentially hazardous gas in homes people were instructed to open doors and windows for 15 minutes. Between 40 and 50 break-ins were reported upon return from the week-long evacuation.

The accident did not result in any deaths or major injuries; however, minor and temporary health effects were reported; including eye irritations, respiratory problems, chest pains, food poisoning, various psychological and psychosomatic illnesses, existing illnesses aggravated by the experience, and various bruises, sprains, and broken bones. All injuries occurred rarely, affecting less than 1% of the evacuees, except for nervousness and anxiety, which was reported by about 11% of those interviewed in August 1980.

5.2.2 Mt. Vernon Propane Tank Car Derailment

On Thursday, April 22, 1981, at approximately 5:45 p.m., a tank car carrying 25,000 gallons of propane derailed on a spur near downtown Mt. Vernon, Washington. "The tank car remained upright and appeared to be undamaged" (Perry and Mushkatel, 1986: p. 12). Initial efforts of railroad employees to get the tank car back on the track were unsuccessful. The railroad workers did not define the situation as posing any danger and decided to close off the spur for the night. They planned to right the tank car as part of the following day's work. At about 7:45 a.m. an employee of an adjacent business noticed a tank car marked "liquefied petroleum gas" and reported it to county authorities. The railroad crew's failure to notify local authorities was identified in retrospect as the single biggest mistake associated with the incident.

The local fire and police departments, the county emergency services agency, and the county police played key roles in handling the incident.

On-site inspections conducted by emergency responders indicated that no hazardous materials were being released into the environment. While the failure to report the incident resulted in a strained relationship between community emergency responders and railroad responders, it was agreed that the unmolested tank car did not present a major threat to the surrounding community. Community officials reasoned that lifting the tank car back on the track could produce sufficient strain to cause any preexisting weak spots to fracture, and release propane into the environment or cause an explosion that would be complicated by the existence of other liquid petroleum products stored nearby. Railroad officials argued that the operation posed no threat to the community. While there was no reason to suspect preexisting weak spots, there was also no immediate way to confirm that they did not exist.

About 16 hours after the derailment, at about 10:00 a.m., emergency officials started the process of a door-to-door, notification of surrounding residences and businesses advising people to evacuate the area. An elementary school and a nursing home also were evacuated. County police blocked off primary streets near the derailment site at 11:00 a.m., and by 12:30 p.m. approximately 2500 people had been evacuated. The tanker was returned to the tracks without further complications, and people were allowed to return to the area about 1:00 p.m. The evacuation was characterized as precautionary rather than a response to an extant disaster.

5.2.3 Denver Nitric Acid Spill

On Sunday, April 3, 1983, in a rail yard near the central business district of Denver, Colorado, a railcar coupling punctured a tank car containing 18,000 gallons of nitric acid. Initially, a small fire was ignited, and a cloud of nitric acid gas engulfed some nearby electrical transformers causing explosions and resulting in power outages in the surrounding areas. While the nitric acid spill itself presented little threat to nearby residents, the gaseous plume that formed over the rail yard was subject to rapid spreading by the wind. Emergency managers confirmed the existence of the toxic plume, plotted the downwind trajectories and identified the immediate need for evacuating threatened areas.

In coordination with the Denver Fire Department, the Denver Office of Emergency Preparedness decided to evacuate a 500 square block area adjacent to the rail yard. Part of the evacuated area is comprised of factories, warehouses, and industrial areas. In addition, there are a number of low-income inner-city residential areas, populated primarily by minorities (i.e., Mexican-Americans, Blacks, and a small number of Cambodian immigrants). By 5:30 p.m. the warning process had begun with the sounding of emergency sirens. Additional warnings were broadcast over television and radio, and emergency personnel engaged in a door-to-door alert in some areas and used portable loudspeakers in others. Official estimates indicated that more than 4000 people were evacuated, but only 2300 registered at public shelters. By noon of the following day, most of the nitric acid had been neutralized with soda ash, and the cloud had

dissipated. A number of people were treated for minor eye irritations and respiratory difficulties in the course of the emergency, but no serious injuries were reported.

5.2.4 Pittsburgh Phosphorous Oxychloride Release

On Saturday, April 11, 1987, at 12:29 p.m., a westbound Conrail freight train derailed in Pittsburgh, Pennsylvania. In the process of derailing, the westbound train sideswiped an eastbound train causing it to derail. Four of the derailed tank cars on the eastbound train contained hazardous materials. Sparks resulting from the accident ignited a fire; however, "... contrary to reports circulated at the time of the accident, none of the hazardous materials ignited" (Railroad Accident Investigation Report, No. A-63-87, Consolidated Rail Corporation, Pittsburgh, Pennsyl-vania, April 11, 1987). Because of the involvement of hazardous materials, Pittsburgh emergency personnel initiated an evacuation when they arrived at the scene, about 20 minutes after the accident. Some local residents in the immediate adjacent areas had already begun to evacuate. Up to 22,000 people were evacuated as the initial evacuation area was expanded to accommodate changing weather conditions.

The fire was extinguished by 3:30 p.m.; however, the primary concern centered around a derailed tank car containing phosphorus oxychloride. This tank car developed a crack in the dome that permitted between 30 and 100 gallons of lading to escape. Emergency response teams inserted a tennis ball in the vent pipe to prevent further release and neutralized the chemicals that had escaped with hot ash and sand. By 5:50 p.m. the affected areas had been declared safe and the initial evacuation order was rescinded.

Emergency officials planned a second precautionary evacuation for 1:00 p.m. the following day to upright the leaking tank car; however, a close inspection of the damaged tank car shortly after midnight detected continued degradation of the tank car. At 1:30 a.m. an evacuation order was issued affecting between 14,000 and 16,000 residents within one-half mile of the scene. This second evacuation order was not rescinded until 4:30 p.m. on Sunday, April 12, 1987. Approximately 25 people were treated for eye and throat irritation at area hospitals, and three people were hospitalized during the course of the accident.

5.2.5 Confluence Precautionary Evacuation

On Wednesday, May 6, 1987, at 4:10 a.m., 21 of the 27 "empty" tank cars carrying product residues including propane, chlorine, caustic soda, carbon disulfide, methyl chloride, chloroform, and isobutane derailed in Confluence, Pennsylvania. Because tank cars carrying residue can haul up to 3% of the load, emergency officials had no way to determine the exact amount of products remaining in the cars. Upon examination of the train's

manifest, emergency management officials initiated a precautionary evacuation of the 986 residents.

A 3-minute nonstop siren blast was sounded, which primarily alerted the volunteer firemen; residents could not be expected to be aware of the siren-blast's specific meaning. At approximately 4:30 a.m., a door-to-door and portable loudspeaker alert and notification of the emergency began using volunteer firemen and untrained volunteers. Public shelters were set up in the area's high school, and local school buses and ambulances provided transportation for those needing it. The evacuation was complete within 45 minutes. With the assistance of area-wide emergency personnel, two leaking propane tankers were sealed by 9:48 a.m. The chance of explosion and/or fire during wreckage cleanup prevented the evacuees from returning until 6:10 p.m.

5.3 TIMING OF WARNING AND RESPONSE

In two recent train derailments (i.e., in Pittsburgh, Pennsylvania and Confluence, Pennsylvania), data regarding the timing of warning receipt were collected by the University Center for Social and Urban Research at the University of Pittsburgh. These data are summarized in Fig. 2 as the cumulative proportion of the population warned by time of receipt in terms of minutes into the event. The measurement difficulties are clearly evidenced by the proportion of respondents that reported receiving warning prior to the event's occurrence. This seems to occur at least partially because of the way people think about and recall time. For example, the noontime Pittsburgh event actually occurred at 12:25 p.m., but many of those reporting warning receipt prior to that time said they were warned at noon. It is not hard to construct that many people would recall the time in terms of what they were doing at the time (e.g., eating lunch) and report it as noon (i.e., 12:00 p.m.).

Both warning situations are characterized as consisting of primarily route-alerting and door-to-door warning systems. Each warning situation is characterized by an S-shaped curve, with the Confluence event reportedly approaching 90% warned in about 2 hours, and the Pittsburgh event reportedly approaching 80% warned in about 3 hours. However, because of methodological uncertainties, it is only possible to identify people that positively report having received some kind of warning; it is not possible to identify those not receiving warning. While the warning situations in Confluence and Pittsburgh are characterized by rapid dissemination within 1-1/2 hours of the event, only 12.5% reported being warned within 15 minutes in Pittsburgh, and 36.8% reported being warned in the same period in Confluence. This may be attributed to a number of factors including the type of event, the size of the area to be warned, distance from the source, time of day, or a bias associated with attributable experience gained vicariously in Confluence when the Pittsburgh event occurred (about a month earlier). In Confluence nearly 70% report receiving a warning within 1 hour, while only 23% report having received a warning in the same period in Pittsburgh. Neither event is characterized by complete (100%) warning, and both events indicate that very rapid onset

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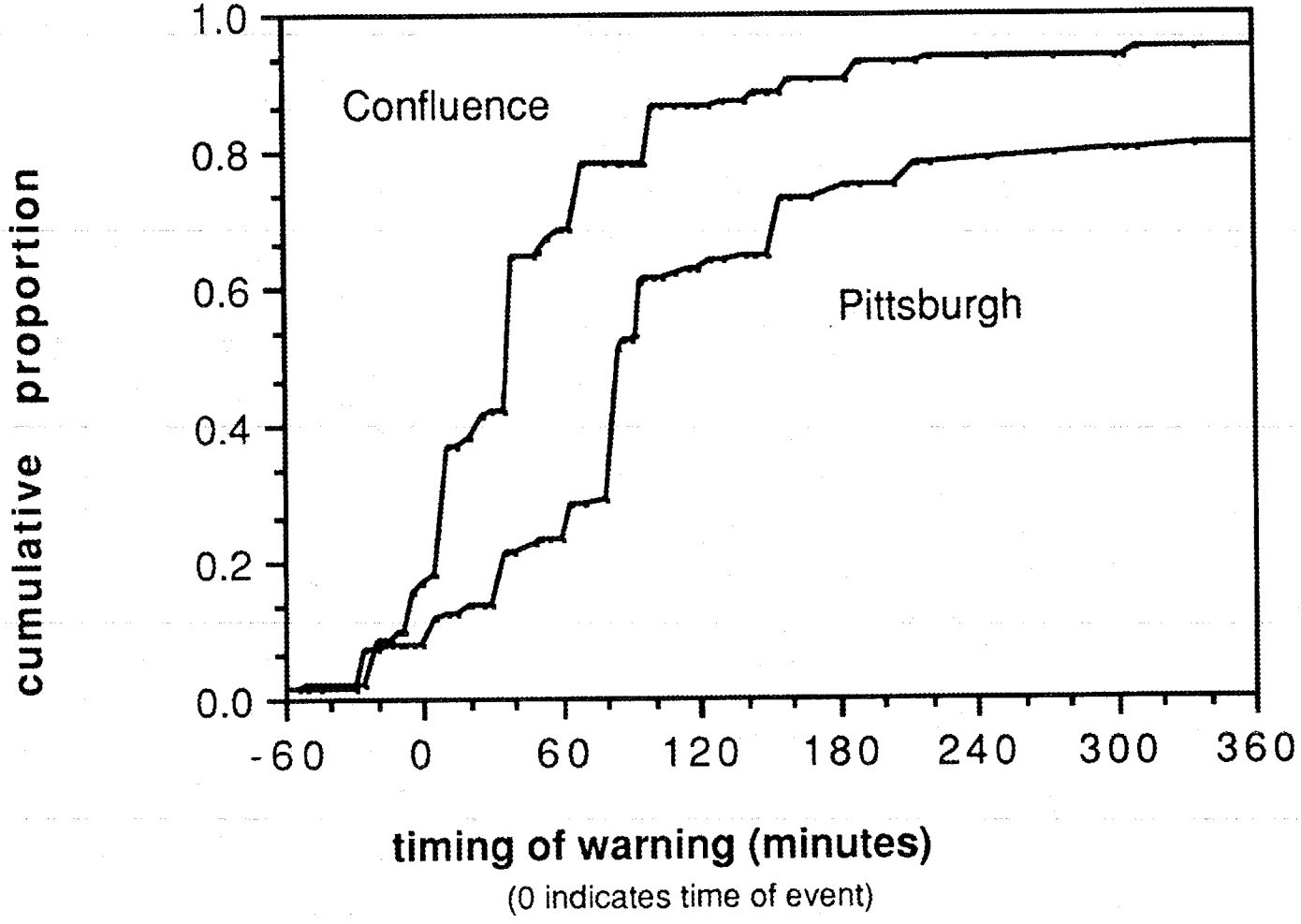

Fig. 2. Timing of warning received.

emergencies can result in people being engulfed in danger prior to receiving a warning.

Response may be characterized as the passage of time between when people receive the warning message and when they take action to avoid harm. In both the Pittsburgh and Confluence events, the principal response for individuals was to evacuate the affected area. In Pittsburgh, about 22,000 people were evacuated (Railroad Accident Investigation Report No. A-63-67). In Confluence, all 986 residents were evacuated (PEMA, Western Area Office, June 3, 1987 report on CSX Train Derailment on May 6, 1987, in Confluence Borough). The response function closely follows the curve representing receipt of warning in the Confluence event, while in Pittsburgh response was both slower and more limited. This may result from the simply defined area at risk (i.e., the entire Borough of Confluence), the simply defined response options (i.e., evacuate to ...), the vicarious experience of hearing about the evacuation in Pittsburgh, the perception and personalization of risk, or the social context associated with community size.

The dynamics of the two events are also quite different in terms of the time of day. The Confluence event occurred at approximately 4:20 a.m. on Wednesday, May 6, 1987. Most people report being at home in bed when they first received warning. In contrast, the Pittsburgh event occurred at approximately 12:25 p.m. on Saturday, April 11, 1987. Some people were at home, (e.g., working in the yard), but many reported being away from other members of their families (e.g., shopping in the area, at community functions, and at work). In short, the social dynamics of the time of location by time of day and day of week are a contributing factor in the apparent difference in the warning and associated response for the two events.

5.4 SOURCE OF WARNING

In both the Pittsburgh and Confluence events, portable sirens and loudspeakers along with door-to-door warnings account for the majority of the warnings received (58.5 and 89.0%, respectively) (Table 3). This is in addition to the 66.7 and 27.5% reporting a visible or audible sign of the disaster in the two communities. All of these route-alerting methods of warning took 1 to 1-1/2 hours on the average in Pittsburgh; portable sirens in Confluence averaged just over 30 minutes and loudspeakers and door-to-door alerting took about 1 hour. The most effective warning source in terms of average time to warn in Pittsburgh was the contagion of the warning message through the social network. Unfortunately, comparable data are not available for Confluence. It is interesting that even among those that reported audible and visible signs of the events, average warning times are reported at 85 and 50 minutes after the event, respectively. Therefore, it seems evident that respondents associated special meaning to an emergency warning. They probably associated it with being told by officials and/or authorities.

Table 3. Average time warned by source of warning
(in minutes into the event)

Source of Warning	Pittsburgh		Confluence	
	N	Mean	N	Mean
Friends, neighbors, and relatives	59	49		NA
Portable sirens	61	61	33	32
Door-to-door	38	70	27	66
Portable loudspeakers	89	87	21	68
Radio	21	95		NA
Television	33	96		NA
Other sources	19	92	10	92
Visible/audible sign	214	86	25	58

One of the primary protective actions used in each of these events was evacuation. The average response time among those evacuating was 24.2 minutes in Confluence and 26.5 minutes in Pittsburgh. Route alerting, characterized by officials either at the door or using loudspeakers, generated slightly faster responses than did portable sirens alone in both events (Table 4). In Confluence, these authority-based route alerting mechanisms generated response in 20 to 25 minutes on average, while in Pittsburgh these same sources achieved a response in about 50 minutes. Response to portable sirens alone took about 20 minutes longer in Pittsburgh, while portable loudspeakers took longer than other sources of warning in Confluence. Presumably, this is the time it takes to determine the nature of the event and what should be done about it.

Figure 3 illustrates the timing of warning and response for both events expressed as the cumulative percent hearing and responding to the warnings.

5.5 WARNING EFFECTIVENESS

An effective warning system, from a public response viewpoint, is one that provides both a timely alert and notification and a message that guides people to take the appropriate protective action. A timely alert and notification is one that gives the public sufficient time to implement the appropriate response. An effective message is one that has the appropriate content and style and is disseminated over multiple channels with frequent and up-to-date information. Previous research has identified the elements of both style and content that are thought, from a normative standpoint, to define effective message design.

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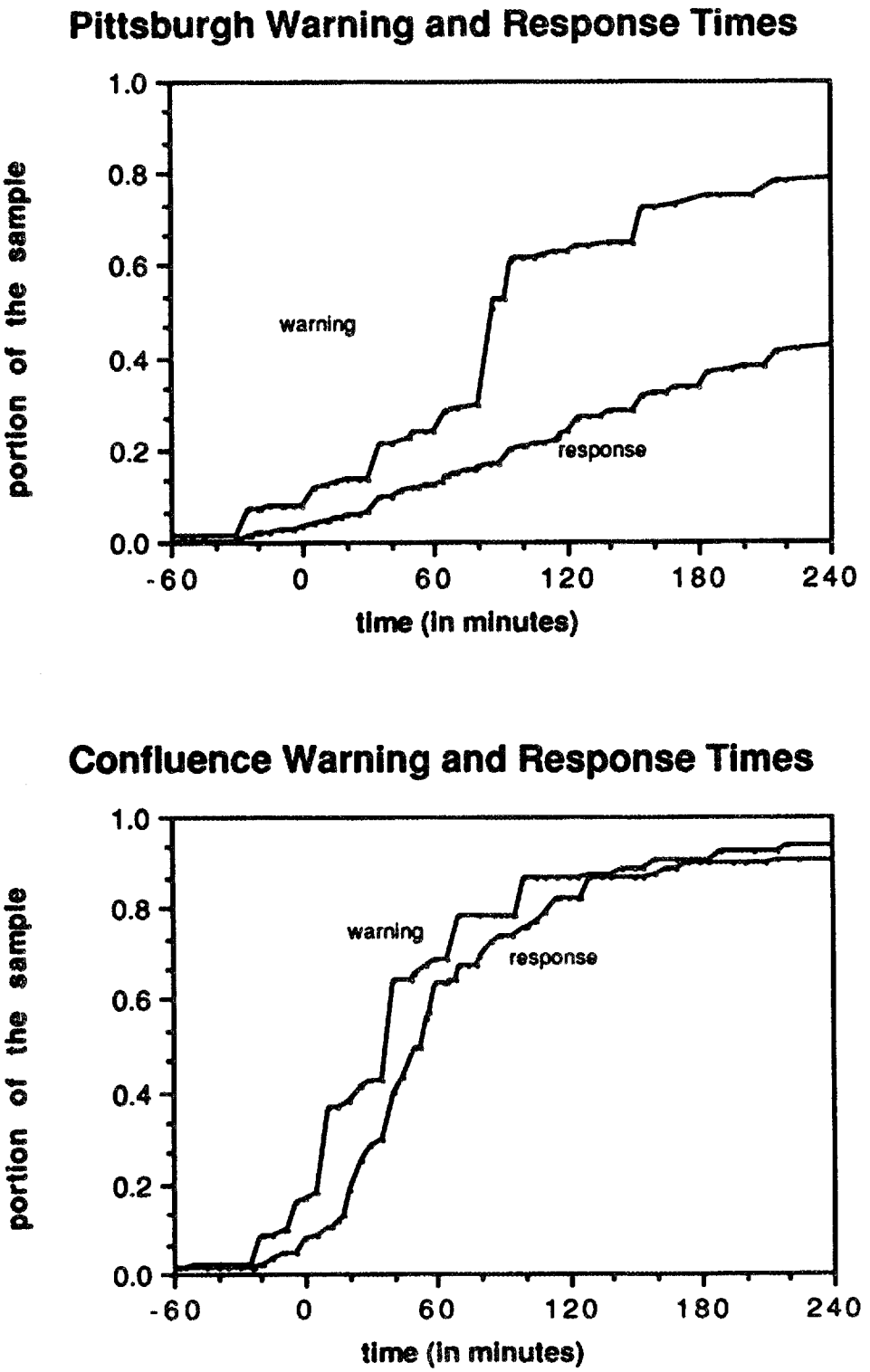

Fig. 3. The timing of warning and response for both the Confluence and Pittsburgh events.

Table 4. Average response time to emergency warning by source of warning (time in minutes)

Source of Warning	Pittsburgh		Confluence	
	N	Mean	N	Mean
Friends, neighbors, and relatives	59	54.4		
Portable sirens	22	73.4	33	21.5
Door-to-door	37	50.4	11	25.9
Portable loudspeakers	86	49.3	21	38.0
Radio	20	59.3		
Television	33	57.4		
Other sources	19	30.8	10	13.3

5.5.1 Timing and Source of Warnings

The speed at which an alert and notification can be disseminated to the public is largely a function of the following factors:

1. Type of warning system
2. Time of day
3. Area at risk
4. Population distribution
5. Season
6. Weather conditions
7. Reliability of warning system technology

From a series of historical events, the percentage of the population warned before an event occurred using an ad hoc warning system, which typically relies on (a) the media and EBS, and door-to-door or (b) route alerting, can be estimated from behavioral surveys conducted following the event (Sorensen and Mileti, in press; Sorensen et al., 1987). In these cases, the percentage warned ranged from 30 to nearly 100% of the population that was defined by the researcher to be at risk and included in the sample. The poorest warning effort documented by a behavioral study was at the Big Thompson, Colorado, flood where an estimated 30% received a warning before the flood waters came. In other disasters such as the 1976 Buffalo Creek, West Virginia, flood and the 1977 Johnstown, Pennsylvania, flood where behavioral surveys were not conducted, it is likely that lower warning rates would be found also. These were fast moving events with less than 1 hour lead time. At Buffalo Creek, no formal warning was issued, and the cascading water provided the only form of notification (Erikson, 1976). In the Johnstown flood, the failure of communications equipment led to a situation in which warnings failed to reach most of the public (NOAA, 1978).

In events where detection provides a lead time of a minimum of 3 to 4 hours, 90 to 100% of the population can be warned without the use of a highly specialized warning system in most events. The warning systems used for these events are ad hoc. They involve a combination of emergency efforts including door-to-door notification by law enforcement personnel, driving through affected areas using portable loudspeakers and sirens on emergency vehicles, and disseminating warning over radio and television stations including the EBS. Permanent sirens or other more sophisticated warning technologies were not used to warn the public in these events.

Figure 4 relates the level of warning to the available warning time for 14 historical events. The data is used to show three curves of warning penetration based on short-, medium-, and long-lead times. The curves were derived by fitting a logarithmic regression function to different sets of the observed warning rates. The logarithmic function is used because it best approximates the nature of the data in the Mt. St. Helens ashfall case. The penetration of warnings during the first 50 minutes of all warnings and for all warnings of 1 hour or less is believed to be best represented by the curve:

% warned = 81.83 * available time^3.488 .

For events with 50 to 3 hours of warning time, the curve is characterized by the equation:

% warned = 59.58 * available time^0.4753 .

Finally for events with warning times of 3 hours or greater, the curve is represented by the equation:

% warned = 66.63 * available time^0.2089 .

Because of the small number of data points that these equations are derived from, the reader should note that the uncertainties associated with the curves are quite large.

People were warned in most events by a combination of three message sources: emergency officials such as police officers or emergency workers who go door-to-door or through the streets with loudspeakers; informal sources such as friends, neighbors, or relatives who make personal or telephone contact; and the mass electronic media such as radio or television. The mixture of warning sources varies among events, although the reasons for variations are not well understood.

One factor that differentiates the various combinations is the available warning time (Fig. 5). In events with only a short amount of warning time, the prime mode of warning is local officials and informal contacts. Often these events may occur during the nighttime hours when people are not tuned to the media. The media plays a more important role in short-fused events that occur during the day or in the evenings. In addition, the media plays a significant role in events with long lead times. In such situations, officials do not provide the initial warning

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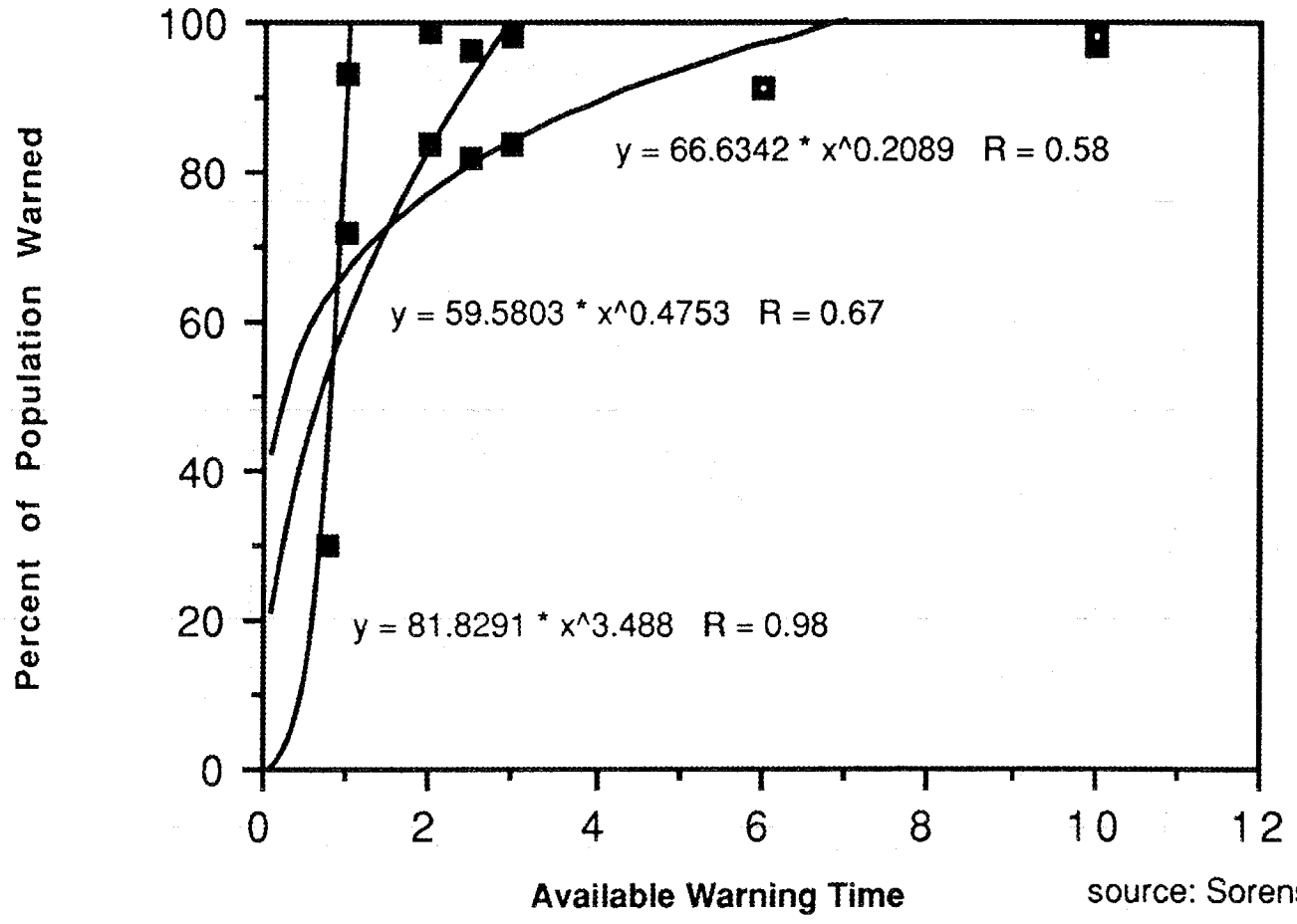

source: Sorensen and Mileti, 1988

Fig. 4. Three warning rate curves.

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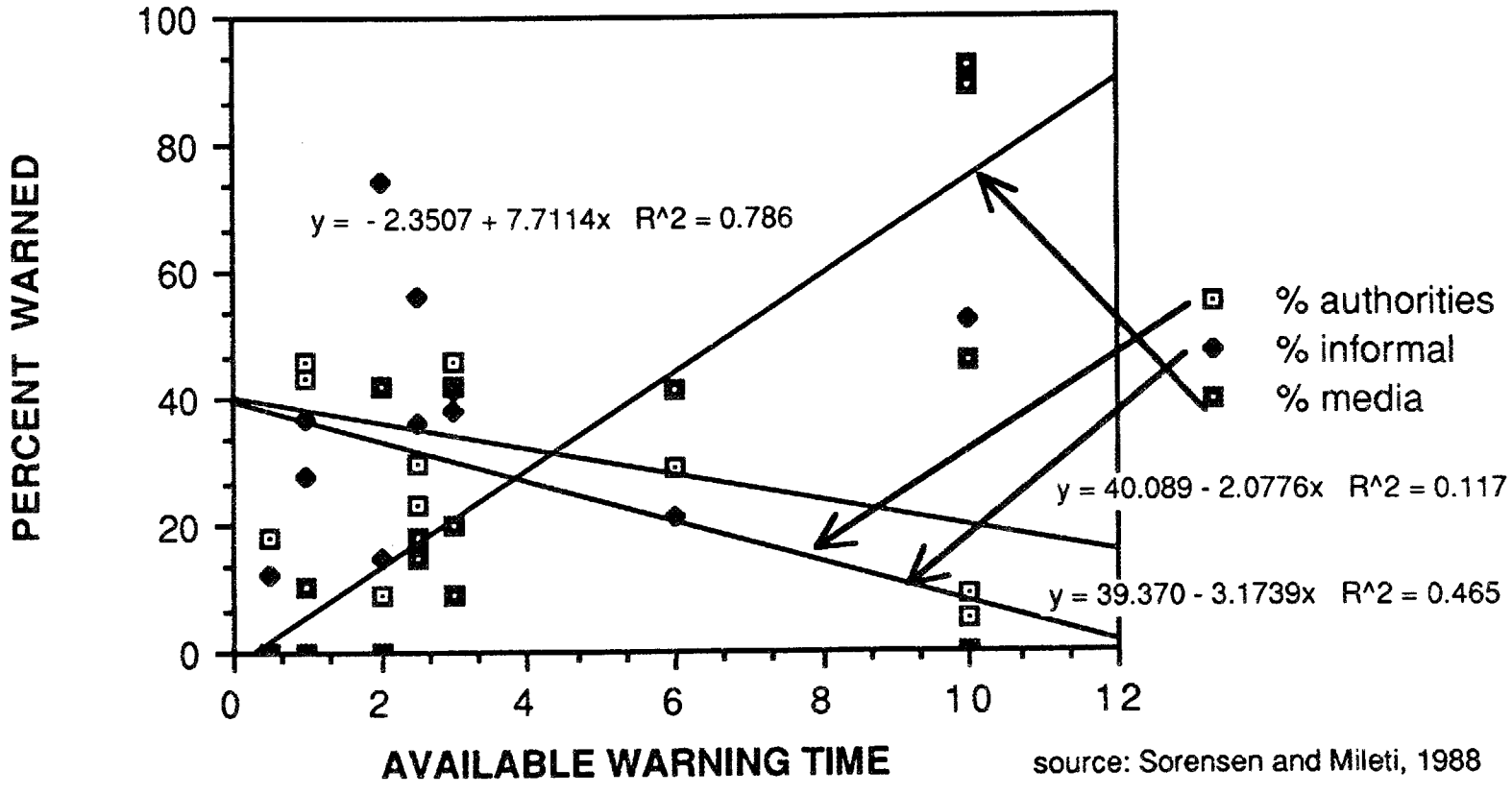

Fig. 5. Percent warned by source and time.

but may provide personal notification of people in high-risk areas. The data also suggest that informal warning is a likely social process in a warning situation. In the events that have a very short lead time, it appears that for about every household that receives a warning from an official another household is notified informally before officials can provide the warning. In more diffuse situations, the role of informal warning diminishes. Thus, the actual timing of the warning dissemination is greatly accelerated by social processes that seem to occur in most disasters. In longer events, warning information is exchanged on an informal basis by many of the people at risk even though the first notification is not from an informal source.

Another way of viewing the timing of ad hoc warning is to examine the rate at which the members of the public at risk are warned. Figure 6 depicts the rate of warning, measured as the number of households warned per minute by the amount of available warning time and the number of households warned for nine localized and fast-onset hazard events. In general, as the size of the population at risk increases, the rate of warning also increases. That is, the capability of the warning system expands as the population involved becomes larger. This reflects the fact that resources such as police and other emergency personnel are proportionate to the population in a community. Warning rates decreased as the amount of time available to warn increased. It appears from the data that a warning rate of 30 to 35 people per hour is a maximum for these types of situations. The warning rate in very large locations may be greater as would be the rate where media is used over a longer warning time period.

The historical data fail to reflect what is theoretically possible to achieve given specialized warning technology. The Lachman and Bonk (1960) study of the Hilo Tsumani indicated that 95% of the population heard the warning sirens within minutes. Studies around nuclear power plants suggest that the portion of the population that hears warnings from the test soundings range between 60 and 95% depending on weather, season, and time of day (Towers et al., 1982). The Federal Emergency Management Agency (FEMA) tests of siren systems around nuclear power plants indicate a similar range with a mean of 85% alerted by test soundings of sirens (FEMA, 1988). The larger problem is response to an alert mechanism. It is not known how many people actively seek information when they hear a siren. The length of time that it takes to receive a warning message following the alert is largely unknown, but it is likely to be a logistic function that falls between the function for the hearing of a siren and that for systems based on official notification.

Other specialized warning systems capable of rapid warning of a high percentage of the population include tone-alert radios and automatic telephone dialers that would have steep penetration curves. Both systems are capable of providing an alert and an instructional message. Recent experiences with tone-alert radios suggest that about 70% of the households served by such a system had operating systems that produced a warning that was heard by people at home at the time (FEMA, 1988). The major problem with tone-alert systems is having an operable receiver. No

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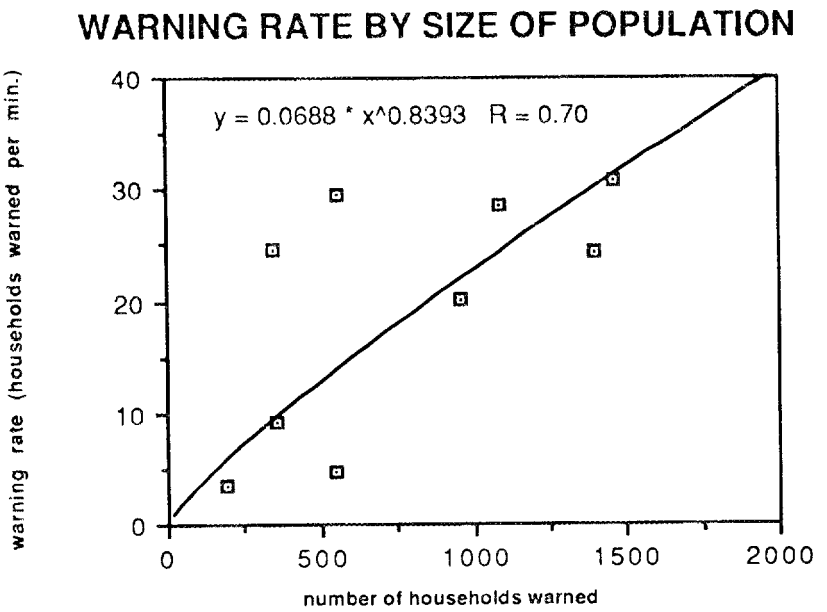

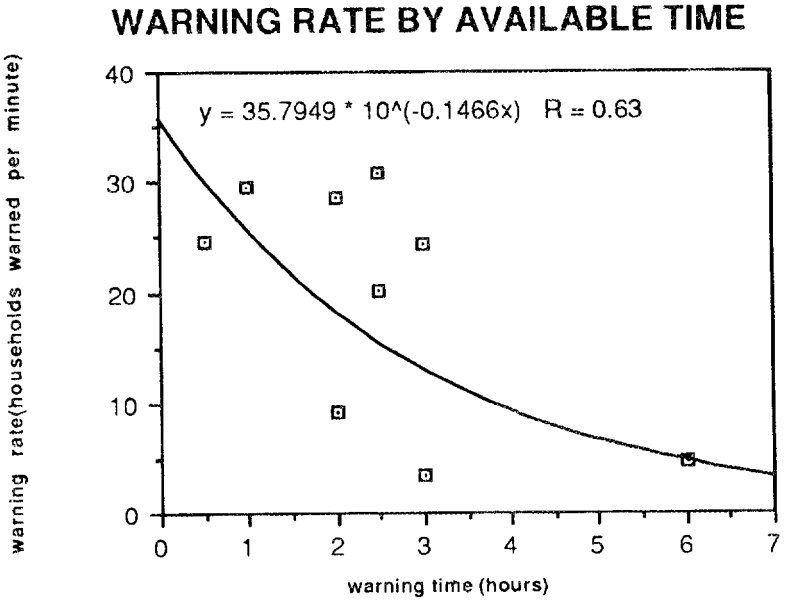

Fig. 6. Warning rate by size of population and by available time.

data exist on the actual performance of a telephone-based system in a test or in an actual emergency.

5.5.2 Notification Effectiveness

A large number of studies exist on factors that influence public response to warnings (see Sect. 2.3). An effective warning system will incorporate such information into the system design. Those factors can be divided into sender and receiver characteristics. Table 5 provides a categorization of those factors.

Sender characteristics are attributes of the actual warnings received by members of the public who will or will not respond to those warnings. Sender--or warning--characteristics fall into four general categories. These categories are attributes of the messages, attributes of the channels through which messages are conveyed, attributes of the frequency with which messages are given, and attributes of the person(s) and/or organization(s) from which the messages emanate (source attributes). Empirical findings from research on sender characteristics suggest that message attributes important to consider in understanding variation in human response to warnings vary in reference to both the content and style of the message. Message content that effects response includes information about the location(s) at risk or not at risk, the character of that risk (for example, effects of impact and time to impact), and guidance about what people should and should not do in response to the warning and before impact. Both message style and message content are important considerations. Research suggests that the message style attributes that are important are specificity (the degree to which the message is specific

Table 5. Factors affecting warning response

Sender Characteristics
Message attributes (style and content)
Frequency attributes (number and pattern)
Source attributes (officialness, credibility, and familiarity)
Channel attributes (type and number)
Receiver Characteristics
Environment attributes (cues and location)
Social attributes (network, resources, culture, and activity)
Psychological attribute (knowledge, cognition, and experience)
Physiological attributes (disabilities)

about risk, guidance, and location); consistency (the degree to which a message is internally consistent, and the degree to which consistency of information exists across separate warning messages regarding risk, guidance, and location); accuracy (the extent to which message content about risk, location, and guidance is accurate); certainty (the degree to which those giving the warning message seem certain about what they are saying about risk, location, and guidance); and clarity (the degree to which risk, location, and guidance information in the message are given in words that people can understand).

In addition to message attributes, the characteristics of the channel used is significant. These include the type of channel used (i.e., personal versus impersonal) and the number of different channels used. Frequency attributes include the number of times a particular message is conveyed, the number of different messages, and the pattern between different conveyances (i.e., every 15 minutes, randomly, etc.). Source attributes include the level of familiarity of those giving the message to those receiving it, whether the message giver is an official, and the credibility of the message giver to those who receive the message.

Research also documents a variety of characteristics of those who receive warning messages and covariants of warning response process factors. These receiver characteristics are divided into four major categories of receiver attributes. The first of these is attributes of the environment of the warning recipient when the warning is received. The environmental attributes worth noting are physical and social cues (e.g., if there is smoke coming from the chemical plant when warnings are received, or if neighbors are seen evacuating when evacuation advisements are received).

Social attributes of the warning receiver that have been empirically demonstrated to covary with warning response and process factors have been grouped into five categories. Aspects of the social network of which the warning recipient is a member is one category that includes factors such as whether the family is united, social ties and bonds, the existence of close-by friends and relatives. Resource characteristics of the warning recipients is another category of social attributes that refers to physical resources such as having or not having access to a car in which to evacuate, economic resources such as having money to pay for a hotel, and social resources such as having or not having a local social support system. The role characteristics (i.e., sex and age) of the warning recipient are social attributes that affect warning response. Role characteristics include, for example, sex and age. Cultural characteristics such as ethnicity, language, and social class are another dimension of social attributes. The last category of social attributes of the warning recipient is activity characteristics; that is, the social activities in which the warning recipient is participating when the warning message is received. These include activities such as sleeping, working, and recreating.

The third set of attributes of the warning recipient revealed by past research as necessary considerations are psychological attributes. These include pre-warning knowledge about risk associated with a particular hazard, protective actions, and the existence of emergency plans; pre-warning cognition such as psycho-social stress level and locus of control of the warning recipient; and experience with the hazard, for example, the type of experience and its recency.

The last set of warning recipient attributes in the typology of attributes suggested by past research are physiological attributes. Although relatively scant, empirical research has been performed on physiological attributes, factors such as physical disabilities--for example, deafness and blindness--are a category of warning receiver attributes that can effect warning response and process.

From an emergency management standpoint, another way to look at warning system effectiveness is to measure the warning system's ability to provide populations at risk with adequate time to respond appropriately to the situation. The consideration of how much time it takes to warn the public is relatively unimportant until it is considered in conjunction with the onset of the hazard. Hence, it is the available time for effective response that is the single most important measure of warning system effectiveness. For example, a warning system that warns a population in 10 minutes, when the population is exposed in 8 minutes is less effective than a warning system that provides warning in 1 hour when exposure takes 1-1/2 hours.

Three hypothetical situations are used to characterize the onset of a hazard for comparative purposes. Let us posit hazards that emanate from a source at a rate of 1, 3, and 6 meters/second. These could occur as the result of a toxic vapor cloud emanating from a fixed chemical facility or a transportation accident. Historically, the accidents at Bhopal, India, and Institute, West Virginia, represent the former, and the accidents at Mississauga, Ontario, and Pittsburgh, Pennsylvania, provide historical examples of the latter. In accidents with airborne toxins such as these, the variable rates are attributable to differing meteorological conditions and, in particular, wind speed.

Rogers and Sorensen (1988) simulate the diffusion of warning for six types of warning systems, including systems based on fixed sirens and alarms, tone-alert radios, auto-dial telephones, media and the EBS, as well as combining systems based on sirens and tone-alert radios and sirens and auto-dial telephones. It is assumed that the process of deciding to warn can be improved to take about 10 minutes. Such a time is about twice as fast as the average time reported for communities to make the decision to warn under ideal conditions in a fast moving event of just over 18 minutes, which does not include facility time for detection, assessment of the hazard, and any subsequent decision-making time. Longer or shorter decision times change the probabilities of being alerted prior to hazard onset, but the relative performance of each warning system remains unchanged. Organizational decision-making time is variable given the nature of the emergency event. At Bhopal,

approximately 20 minutes elapsed before the alarm, and the public alarm was apparently shut down completely for nearly 30 minutes after that (Morehouse and Subramaniam, 1986). In other types of disasters, such as the Cheyenne flash flood, public warnings began to be issued within 5 minutes of detection (Sorensen 1987a). Rogers and Sorensen (1988) consider a critical area of 35 km from the source of the hazard. Beyond that distance, no specialized warning effort would be needed to provide sufficient time to disseminate the warning using ad hoc warning procedures.

By combining the diffusion estimates for various warning systems with the hypothetical "downwind" travel speeds, the probability of warning people prior to exposure at various distances from the source of release is estimated (Table 6). These results indicate that the amount of time it takes an organization to decide to warn, including the detection of the hazard, is a critical component of warning system effectiveness. The resulting estimates demonstrate the critical nature of organizational decision making in all events but place even more emphasis on this crucial element of emergency warning where warning time is most limited. People cannot fully protect themselves from a hazard when they do not receive warning prior to exposure. These results also imply that the full range of potential protective actions be considered. In chemical emergencies, eight evacuees in every 100 are injured because of inhalation of toxic vapors (Sorensen, 1987b). Alternatives to formal evacuation in fast-onset events include escape and sheltering. Escape consists of the moving afoot out of the endangered area (Prugh, 1986). Sheltering involves movement to secure places in a structure and taking steps to keep the hazardous agent from entering the structure. In chemical incidents, sheltering may be an extremely effective way of self-protection. Both actions are viable alternatives to evacuation because of the relatively short time required to implement these actions.

The combination of either telephone ring-down or tone-alert radio warning systems with sirens provides the most effective warning system under conditions of very rapid onset, close proximity, or both. These results indicate that alternative individual systems provide adequate warning effectiveness when available warning time (to the public after detection and the decision to warn) extends to as much as 1 hour, and that tone-alert radios and telephone ring-down systems provide similar coverage at approximately 30 minutes of available public warning time.

The results indicate that a combination warning system is the most effective system in the 10-km radius. Given the instantaneous release at low onset speeds, most people in the 10-km zone will receive a warning. At the onset speed of 3 meters/second, the combination systems do not lead to adequate warnings within 2 kilometers, but they perform well within the 5- to 10-km range. Under very high onset speeds, it will be difficult to adequately warn people within 5 km.

Within 35 km some multiple method warning systems may also be desirable, although 100% overlap is not necessary. A combination of

Table 6. Available time and distance for warning system alternative (assumes a decision to warn in 10 minutes)

Warning system	Distance (km)				
	1-2	2-5	5-10	10-20	20-35
Windspeed of 1 m/s min (+0.5) +	15.5	48.8	115.5	240.6	448.9
Sirens and alarms	0.563	0.855	1.000	1.000	1.000
Tone-alert radios	0.811	0.939	0.999	0.999	0.999
Auto-dial telephones	0.882	0.971	1.000	1.000	1.000
Media/EBS	0.199	0.595	0.843	0.927	1.000
(A & B)	0.925	0.993	1.000	1.000	1.000
(A & C)	0.941	0.993	1.000	1.000	1.000
Windspeed of 3 m/s min (+0.5) =	-1.2	10.0	32.2	73.9	143.3
Sirens and alarms	0	0.296	0.809	0.922	1.000
Tone-alert radios	0	0.610	0.922	0.963	0.999
Auto-dial telephones	0	0.713	0.955	0.996	1.000
Media/EBS	0	0.102	0.473	0.693	0.893
(A & B)	0	0.759	0.977	1.000	1.000
A & C	0	0.816	0.977	1.000	1.000
Windspeed of 6 m/s min (+0.5) =	-5.3	0.3	11.4	32.2	66.9
Sirens and alarms	0	0	0.390	0.809	0.903
Tone-alert radios	0	0	0.697	0.922	0.957
Auto-dial telephones	0	0	0.792	0.955	0.989
Media/EBS	0	0	0.132	0.473	0.668
A & B	0	0	0.842	0.977	1.000
A & C	0	0	0.882	0.977	1.000

sirens, tone alert, and media/EBS warnings could be used to warn populations within 10 to 20 km. The exact mixture needs to be determined on the basis on local geography, potential hazard, and population distribution. Beyond 20 km, it seems appropriate to rely principally on the media/EBS systems, except for institutional populations that require prompt notification in the entire emergency planning zone.

This analysis provides a preliminary basis for planning warning systems for fast moving events such as chemical spills and for assessing the effectiveness of warning systems currently being used. Although this analysis has focused on the timing of a warning, it is recognized that the organizational structure for issuing the warning and the style and content of the warning are also critical factors in the overall effectiveness of the systems. As society creates more and more potentially dangerous hazards such as industrial facilities, chemical weapons, biotech facilities, nuclear power plants, and other unforeseen technologies, the need for careful planning for emergency warnings increases.

6. CONCLUSIONS

6.1 WHAT ARE THE TECHNOLOGICAL CAPABILITIES OF PUBLIC-ALERT SYSTEMS IN USE AT THE SURVEYED FACILITIES AND COMMUNITIES

The technology of public-alert systems includes two types of equipment. The first are communication technologies used to exchange information between people in various organizations that are part of the system. These organizations include the facility and a variety of local government agencies such as emergency services, law enforcement, fire, and administrative offices. The second technology is for disseminating the alert and the notification to the public. The public includes residential, business and commercial, institutional, and transient populations.

The current technologies of communication for interorganizational alert are primarily commercial telephones and radios. More advanced technologies such as pagers, dedicated telephones, and automated alarms are found in only a few settings. The technologies in use will likely be adequate in many circumstances although the probability for failure is greater than with the more advanced technologies.

The current technologies used for alerting and notifying the general public are more varied. The two predominant systems are sirens, which serve as an alerting mechanism coupled with media dissemination of emergency information, and a combination of door-to-door and route notification techniques (vehicles with sirens and loud speakers) coupled with media dissemination of warnings. In a few locations, the more advanced technologies of tone-alert radios and automated telephone systems are used.

The current technologies in use for institutional populations are essentially the same systems. In a few communities, tone-alert radios or automated ring-down telephone systems have been installed to provide a rapid alert and notification. Most communities, however, seem to assume that no special efforts are needed to alert these facilities.

6.2 WHAT MANAGEMENT PRACTICES AND OPERATING PROCEDURES AFFECT THE CAPABILITIES OF THESE SYSTEMS?

Management practices and procedures vary by site. Most locations have some type of emergency plan. Research has shown, however, that possessing a plan is not a sole indicator of effective response. Several more important characteristics of effective systems include having clearly defined procedures, knowing who to communicate with, and having a cohesive interorganizational response network. Less than 50% of the communities studied had clearly defined procedures for receiving an alert, making a decision to warn, and making a protective action recommendation.

Many of the communities have initiated links with the facilities and know the name and title of the person at the facility who is responsible for notification. Furthermore, communities usually have someone assigned as the contact point. In communities where such interactions have not occurred, the chances for an ineffective or untimely warning are increased.

6.3 WHAT ARE THE TECHNOLOGICAL CAPABILITIES OF STATE-OF-THE-ART PUBLIC ALERT SYSTEMS?

A distinction exists between systems that provide an alert, provide a notification, or provide both alert and notification. The alert function of a warning is a signal that something out of the ordinary is occurring that requires people to seek more information. Notification is the process by which people are provided warning messages and information. A combined system serves both purposes. An example of alert technologies includes sirens and alarms. Examples of notification technologies include emergency broadcast systems (EBS), radio and television, and cable override. Examples of dual systems include tone-alert radios, telephone dialing systems, loudspeakers, and public address (PA) systems. Some systems, depending on how they are used, may not fall into precise categories. Helicopters equipped with loudspeakers are considered a dual system, but in reality, they typically do not provide notification because people cannot hear the broadcast message. In the following discussion, the pros and cons of existing technologies are summarized.

6.3.1 Personal Notification

Personal notification involves emergency personnel making door-to-door alerts or delivering personal warning messages to groups of people. 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 primary 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 disadvantage is that it is time consuming, and it may require the commitment of many people and many vehicles.

To support implementation of this method, a plan should be developed for systematically traversing the threatened area and issuing the warning from the highest risk zone to the lower risk zones. A trial run helps to establish the warning time needed to notify the population at risk and a rate for different types of areas at risk.

6.3.2 Loudspeakers/PA Systems

It is feasible to use existing PA systems to notify people in areas that are covered by the systems. This may include various institutional populations or commercial establishments. Many schools, hospitals, prisons, nursing homes, sports arenas, theaters, and 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 supplement other warning-system communication networks because they are useful in reaching small segments of the population in confined settings. To be effective, a communications link to the operators is needed to ensure quick and accurate message dissemination.

Portable loudspeakers increase the speed of warning populations that have no other means for receiving the warning. They are particularly useful during nighttime hours when many people are asleep. Their primary disadvantages are that it is often difficult to hear a warning broadcast from a moving vehicle, and it is difficult to confirm the warning, particularly if only a part of it is heard.

6.3.3 Radio

Radio is 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). These stations usually have arrangements with local civil defense

offices or other government agencies to broadcast emergency warnings for most hazardous situations. Also, other radio stations usually broadcast warnings in most hazardous situations.

The use of radio as a warning channel will continue to be a major practice in emergencies. Prearranged plans for notification and use of standardized messages accelerate the speed with which a warning can be issued over the radio. One disadvantage of the radio is that often a broad area is covered by the broadcast including areas that are not at risk. 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, because of the private operations of stations, problems can arise in priorities regarding warning broadcasts, although this can be largely eliminated with formal agreements and exercises.

6.3.4 Tone-Alert Radio/Pagers

Tone-alert radios are specialized warning devices that can be remotely activated. In addition to providing a warning signal, some types can subsequently broadcast a verbal warning message. The radio operates in a standby condition and 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 that typically has a range of 40 miles. Some radio receivers operate on normal electrical power, and some have battery backups.

An example of an existing tone-alert system is National Oceanic and Atmospheric Administration (NOAA) weather radio. This system covers most of the country's population. Its chief function is to provide continuous weather forecasts. The 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 quick dissemination time, the combination of an alerting signal with specialized messages, and round-the-clock availability. Disadvantages include maintenance problems, power failures, limited broadcast ranges, and difficulties in outdoor use. 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.

6.3.5 Television

Warnings are also broadcast over commercial television. This can be done by interrupting normal programming 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 particularly good for warnings of slowly developing events. It is likely to take longer to issue a warning over television stations except where prewritten scrolled messages are used. One major advantage of television is the ability to use graphic information such as maps or diagrams in the warning.

6.3.6 Cable Override

In many urban areas people watch cable television; therefore, local stations play a less significant role in reaching the public. As a result, systems have been developed for a scrolled or broadcast message over all cable channels. Thus, a person in Cheyenne, Wyoming, watching a Chicago station or a movie channel could receive a tornado warning. Usually the override systems are operated by local civil defense offices in coordination with a cable television station. This requires prearranged conditions and agreements on the use of such system. The same advantages and disadvantages of normal television apply.

6.3.7 Telephone -- Automated Dialers

Two types of automated dialers currently exist: switching and computerized dialing equipment. These systems have the potential to reach a large number of people in a relatively short time. Recently developed switching technology is capable of simultaneously calling hundreds to thousands of exchanges using automatic switching equipment. Some systems will automatically cancel calls on 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. Most all of the modifications and special equipment are installed at the phone company. These systems can play prerecorded messages that can be updated fairly quickly, or they can broadcast messages that provide timely information. It is feasible to have them equipped with a special ring that acts as an alerting function or combine them with telephone hot-lines to provide specialized information.

The primary advantage of telephone warning systems is the ability to quickly disseminate a message to people in their homes. Automatic dialing systems are expensive; therefore, their use is limited by cost factors. The fraction of a large local area phone system that can be contacted simultaneously is not clear. Another problem to consider is that people who are not near a phone will not receive a message. Because of these issues, the current use of automatic telephone systems is primarily to warn 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.

6.3.8 Sirens/Alarms

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

Siren systems are limited in their use by the lack of instructional messages. At best they warn the public to seek further information. Some areas have an intensive program of public education to instruct people in the actions that should be taken when the signal sounds. This may be possible in situations where the same response is desired every time a warning is issued. Multiple signals, such as a wavering signal versus short blasts, are rarely differentiated by the public. The use of different signals as a warning strategy is not very reliable.

Other problems that constrain the use of sirens and alarms are false alarms caused by 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.

6.3.9 Signs

Often warnings cannot be directly communicated to the public in remote hazardous areas. This has prompted the use of permanent warning signs to instruct people in recognizing the onset of a hazard and what to do if one is occurring. Signs can be effective warning devices if they are located properly and if they are visible at the time a disaster 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 proper locations to place the signs.

6.3.10 Modulated Power Lines

Existing electrical power distribution technology enables specialized warning systems that use power line modulations to activate an alert system. When the system frequency (hertz) 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 are the same 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.

6.3.11 Aircraft

In special cases, airplanes 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, prepared leaflets containing a warning message can be dropped. 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. Another problem is obtaining sound systems capable of broadcasting a message that can be heard over the noise of the aircraft.

6.3.12 Current State-of-the-Art

The current state-of-the-art warning system for a chemical emergency must be able to provide both an alert and a notification in a short time because of the potentially rapid speed at which a chemical can be dispersed. The state-of-the-art in a facility-to-community alert would involve the use of an automated alarm with a dedicated telephone line or a tone-alert radio/pager system. Both would require some form of backup such as a 911 emergency system and a two-way radio.

The current state-of-the-art for public warning depends on the proximity of the public to the facility. For people in close proximity to the plant (within 1 to 2 miles), the state-of-the-art system would involve tone-alert radios or a telephone dialing system coupled with a siren and emergency media message dissemination. For more distant populations (5 miles), any one of these three technologies may be adequate.

6.4 WHAT ARE STATE-OF-THE-ART MANAGEMENT PRACTICES AND PROCEDURES?

No standards exist for state-of-the-art management practices or procedures. Research suggests that state-of-the-art is not indicated by a set of paper plans but rather by a planning process that creates knowledge and communications ability among key responders and decision makers. Management requires both control and flexibility; procedures are needed to guide, but not limit, response; communications need to be established and kept open. Such criteria cannot be operationalized in an easy way so as to permit an evaluation of each community studied.

Despite such caveats, plans and procedures offer a surrogate measure of state-of-the-art. While plans are not a prerequisite or guarantee of effective response, they are positively associated with better responses. As such, the clarity and presence of plans are indicators of the quality of management practices.

6.5 HOW DO THE CAPABILITIES OF PUBLIC-ALERT SYSTEMS COMPARE TO STATE-OF-THE-ART SYSTEMS?

Few communities in the study used state-of-the-art communication equipment or warning system technologies. It is clear that some communities do not need such equipment because the risk most likely does not justify the expense. In other communities, the differences are more critical because of more severe threats and a larger number of people and institutional facilities at risk. Overall, the ability of the majority of systems to provide a timely alert and notification is questionable, particularly in a rapid-onset event.

With respect to management practices, few communities had well-developed plans and procedures to guide emergency response. Notably lacking were the capabilities to make decisions. Both lack of procedures and, more basically, knowledge about the information necessary for making a decision suggest major problems with issuing a timely warning. Also lacking were preplanned warning messages and public information programs.

6.6 WHERE CAN SIGNIFICANT IMPROVEMENTS BE MADE IN PUBLIC-ALERT SYSTEMS TECHNOLOGY?

The goal of a warning system is to provide a reliable alert and notification in a short time to as close to 100% of the affected population as possible. Several types of improvements can bring warning technology closer to that ideal.

First, tone-alert radios are theoretically capable of being the ideal indoor warning system. Current effectiveness is chiefly hampered by human factors and not by the system technology. The technology can be improved to reduce human factor problems. One major constraint is that many radio receivers have multiple channels. A single-channel, fixed-frequency radio would ensure that it was always tuned to the proper channel. Many radios need to be reset after a test to receive another signal. An automatic reset would help to ensure that the radio was always ready to receive. In addition, radios are moved around or given away. A means of permanent attachment (like a smoke alarm) would help to ensure that they remained where they were needed.

Second, electronic sirens are now capable of delivering voice messages. Problems still exist in configuring a system that produces an articulated message. Additional development of such technology is needed for an effective outdoor alert and notification system that is not dependent on the media for delivery of the notification.

Third, sirens that produce the tone and volume of an alert signal that is most effective in alerting people indoors and at greater distance are driven by electricity. Sirens that are driven by battery power lack both the range and ability to penetrate buildings. A battery operated siren can be located virtually anywhere and is not subject to

power system failures. Improved battery driven sirens would increase the flexibility and reliability of siren alert systems.

Fourth, the major cause of a siren failure is in the radio controls that activate the sirens. This problem occurs from moisture shorting-out the radio receiver. Improvements could be made to produce a more reliable radio control.

Fifth, one of the major mechanisms currently used to alert the public is route notification. Very little information on the effectiveness of alternative strategies of route notification is available. Additional information is needed to define a state-of-the-art route alerting technology and procedure. Such information would include the type of loudspeaker or siren, the orientation of the electronics on a vehicle, the speed at which the vehicles move and other related factors that may influence the effectiveness of the technology.

Sixth, technologies have been developed to use radios in a way similar to tone alerts. The further development of that technology could provide a widespread capability to alert people in a variety of settings.

Finally, little experience with the automated telephone dialing systems exist, particularly as they apply to use in densely populated areas. Additional documentation of the technology is needed before such systems become a proven warning technology.

6.7 WHAT ARE THE CURRENT ECONOMIC FACTORS ASSOCIATED WITH PUBLIC-ALERT SYSTEMS IN CURRENT USE AND WITH STATE-OF-THE-ART SYSTEMS?

Most of the current systems in use rely on existing community resources. Therefore they require no additional expenditures to be applied to a chemical emergency. The majority of these systems are: civil defense alerting systems, emergency broadcast and other media base technology, route and mobile alerting, tone-alert radios, and telephones. In a limited number of cases, special systems for a chemical emergency have been installed. These systems include sirens, tone-alert radios, and telephone ring-down systems.

The economic factors associated with any given system are variable. They depend on the area covered, the population density and distribution, topography, and the type of warning system used. Even given a single warning technology, variations in costs can be attributed to the choice of equipment. Installation, maintenance, and operations in costs are variables in computing a total warning system cost.

Based on the experience in installing these warning technologies in the nuclear industry, it is possible to estimate some average costs on a unitized basis. A typical state-of-the-art siren system would cost $50,000 to $100,000 for a 1-mile radius; $150,000 to $200,000 for a 2-mile radius; and $600,000 to $1,000,000 for a 5-mile radius. Costs

for tone-alert radios are between $300 to $500 per household. While less experience exists with telephone systems, the cost of installation is estimated at $50 to $75 per household plus a yearly use fee of $30 to $120. In addition to the capital equipment and installation costs, each system requires expenditures for maintenance.

6.8 ARE PUBLIC-ALERT TECHNOLOGIES AND MANAGEMENT UNIFORMLY APPLIED ACROSS SURVEYED FACILITIES?

Public-alert technologies are not uniformly distributed across the communities and facilities studied. Some approach state-of-the-art while, at the opposite end of the spectrum, some have virtually no established capabilities in place. Management practices also vary among communities.

6.9 WHAT ARE THE REASONS FOR VARIABILITY IN THE USE OF ALERT SYSTEMS?

We have yet to analyze the variability in the use of systems. Based on our initial impressions from the data, we hypothesize that such variations are explained by the size of the community, the financial resources available to the community, and the extent of the overall chemical threat to the community (e.g., the number of facilities, geographical location, and facility size). The communities with poor alert capabilities appear to be smaller towns or rural counties without much money to spend on emergency preparedness or emergency planning personnel. Furthermore, they probably do not have an extensive concentration of industry or very large facilities run by major companies. We suspect that the rural south and midwest are more likely to have a greater number of communities with poor alert systems.

6.10 WHERE ARE THE OPPORTUNITIES FOR WIDER DISSEMINATION OF PUBLIC ALERT TECHNOLOGIES, PROCEDURES, AND MANAGEMENT PRACTICES?

The opportunities, in order of priority within each category, initially appear to be as follows.

6.10.1 Technology

1. Improved communication technologies between facilities and communities with additional backup capabilities.

2. Improved public warning technologies in high-risk and densely populated areas.

3. Better communication links between community EOCs and institutionalized populations.

4. Adoption of computerized emergency planning and management systems and decision aids.

5. Improved communications equipment within community emergency response organizations.

6.10.2 Procedures

1. Use of a standardized information protocol to guide community information collection and dissemination during the initial notification from the facility.

2. Adoption of SOPs for initial response to alerts, warnings, decisionmaking, and protective-action recommendations.

3. Adoption of state-of-the-art warning message protocols for both English and non-English speaking populations.

6.10.3 Management Practices

1. Implementation of exercises in communities not conducting exercises and more frequent exercises in other communities.

2. Improving the working relationships between personnel at the facilities and officials within the community emergency response structure.

3. Developing and implementing improved public information programs.

4. Improving the organizational interface and coordination between federal, state, and local planning agencies.

The methods of achieving improved practices are varied and require careful consideration. Among the possible mechanism are improved planning guides, new training courses, video conferences, seminars, workshops, and working through existing programs such as Community Awareness/Emergency Response (CAER) to develop improved planning and management practices.

6.11 WHAT IS THE FEASIBILITY OF IMPROVED PUBLIC-ALERT SYSTEMS?

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 that could rapidly alert and notify the public and is easily installed and maintained, further technological advances would only increase the gap between practices and the state-of-the-art.

At a local level the feasibility of improvement relies on two factors. The first is the dissemination of information on low-cost or no-cost improvements and improvements in procedures and management practices. Major improvements in management practices and procedures can be achieved without major expenditures.

The second is providing funds for improved communication and warning system equipment. It is unlikely that communities have the funds to completely install new communication devices or new warning systems. Improvements in these areas will require assistance to the communities or cost sharing.

At this point, it appears that the improvement of management practices and the development of better procedures to make decisions and to initiate the warning process is more critical than the promotion of better technology, although both are important. The most sophisticated equipment is relatively useless unless it can be used properly. Improvements in decision-making capabilities and communication among decision makers is a prerequisite to implementing state-of-the-art technology.

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APPENDIX A

RESPONSES TO COMMUNITY SURVEY

(N = 137)

COMMUNITIES PARTICIPATING IN THE STUDY AND THEIR DISTRIBUTION BY SIZE AND GEOGRAPHICAL LOCATION

A. Emergency Planning

Q A-1 Does your community have an emergency operations center (EOC)? (%)

45.6	Yes, a permanent dedicated EOC that is maintained in operating condition.
34.6	Yes, a permanent EOC that is also used for other purposes.
12.5	Yes, a temporary EOC that is established when the need arises.
2.2	No, an EOC does not exist.
2.9	Other arrangement

Q A-2 Is there an alternative or backup EOC? (%)

78.7	Yes
22.1	No

Q A-3 About how many personnel (FTEs or full-time equivalents) work on emergency planning in the community?

Mode = 1
Median = 2
15.4% with none

Q A-4 About what percentage of their time is devoted to chemical emergencies?

Mean = 13%

Q A-5 Does someone in the community have formal responsibility for planning for a chemical emergency? (%)

91.9	Yes
8.8	No

Q A-6 Does the community have an emergency plan? (%)

94.9	Yes
5.1	No

Q A-7 Does it have a section on chemical emergencies? (%)

27.2	No
73.5	Yes; if yes, in what year was it adopted?
3.6	Before 1978

5.1	1978-1982
15.5	1983-1985
14.7	1986
30.1	1987
4.4	1988

Q A-8 Is there a special plan or annex for this chemical facility? (%)

38.2	Yes
61.0	No

Q A-9 About how many emergency personnel would be available to respond to an accident at a chemical facility?

Mean number of persons

64	Full-time paid emergency personnel (35 hours per week or more)
9	Part-time paid emergency personnel (less than 35 hours per week)
42	Volunteer emergency personnel
47	Personnel from non-emergency agencies or departments
89	Personnel available from mutual aid agreements
28	Other personnel

B. Communication

Q B-1 Who at the facility has primary responsibility for initially notifying the local community about an emergency at the facility? (%)

50.7	Identified name and position
0.7	Identified name and organization
18.4	Identified position only
1.5	Identified name only
2.2	Identified organization only
25.0	Unknown or blank

Q B-2 Who would notify the community if those persons were not available? (%)

25.8	Identified name and position
0.7	Identified name and organization
0.7	Identified position and organization
27.9	Identified position only
3.7	Identified organization only
38.2	Unknown or blank

Q B-3 Who has the designated official responsibility for receiving an alert from the chemical facility? (%)

51.4	Identified name and position
0.7	Identified name and organization
8.1	Identified position and organization
38.7	Identified position only
1.5	Unknown or blank

Q B-4 Who would they notify if that person were not available? (%)

32.3	Identified name and position
0.7	Identified name and organization
10.3	Identified position and organization
39.0	Identified position only
7.4	Identified organization only
8.1	Unknown or blank

Q B-5 Are there any days of the week and times of day that it would be difficult for the community to receive an alert (either not issued or not received)? (%)

87.5	No
12.3	Yes (please describe when and why; indicate time periods by day and hours and the reasons each period presents difficulties.)
8.0	Nights
3.6	Weekends
0.7	Evenings, nights, and weekends

Q B-6 What communications equipment would the facility use to notify the community of a chemical accident (primary and backup)? (%)

Primary equipment:

65.7	Commercial telephone
35.0	Two-way radio
5.1	Dedicated telephone
3.6	Dedicated radio
2.2	Pager
7.3	Sirens
2.9	In person
13.1	TV or emergency broadcast system (EBS)
7.3	Public address (PA)/loudspeakers
3.5	Alarm system
2.9	911

Backup equipment:

5.1	Commercial telephone
14.5	Two-way radio
0.7	Dedicated telephone
2.9	Dedicated radio
0.7	Pager
1.5	Sirens
2.9	In person
0.0	TV or EBS
4.4	PA/loudspeakers
0.0	Alarm system
0.7	911

Q B-7 What procedure do you follow when the initial warning is received?

3.7	No procedure described
50.7	Vague procedure
46.3	Clear standard operating procedure (SOP)

Q B-8 Please describe the communications equipment within your EOC (e.g., commercial telephone, 911 telephone, dedicated telephone, automatic ring-down system, manual alarm, automatic alarm, radio, computer link, or other)

85.3	Commercial telephones
79.4	Two-way radio
33.1	911 system
28.7	Dedicated telephones
19.1	Automatic ring-down system
11.0	Manual alarms
5.1	Automatic alarms
19.9	Teletype/computer link

Q B-9 How often is this communications equipment routinely tested? (%)

2.2	Yearly
4.4	Semiannually
25.7	Monthly
17.6	Weekly
45.6	Daily
3.7	Never or blank

Q B-10 Please describe any mobile communications resources available to the community. (%)

11.0	None reported
6.6	Portable radios only
39.7	Radios in vehicles
43.3	Mobile communications vehicle

Q B-11 What information does the community need from the chemical facility in an emergency notification to make a decision to warn the public? (%)

79.4	Type of chemical
56.6	Size of release
36.8	Plume location (actual or projected or wind direction)
11.0	Plume size
24.3	Speed of dispersion (or wind speed)
7.4	Duration of release
41.9	Human health effects
22.1	Pathways
2.9	Available protective actions
19.9	Recommended protective actions
12.5	Facility response
13.2	Assistance needed
44.9	Other (mostly general information, e.g., What happened)

Mean = 3.7 items mentioned

Q B-12 The emergency warning system to alert and inform the public in the event of a chemical emergency at the facility is primarily made up of (%):

33.1	Fixed (permanently installed) mechanical sirens
22.1	Fixed electronic sirens
9.6	Fixed horns, bells, or whistles
12.5	Fixed loudspeakers/public address
5.1	Fixed flashing lights/strobes
67.6	Portable loudspeakers/public address
41.9	Portable sirens/whistles
35.3	NOAA Weather Radio
71.3	Emergency broadcast radio station
37.5	Tone alert radios
32.4	Radio pagers
5.9	Automated telephone dialers
37.5	Other

Q B-13 Is there a person in the community with the responsibility of maintaining communications with the facility during an emergency? (%)

46.3	Identified name and position
7.4	Identified position and organization
25.7	Identified position only
5.1	Identified organization only
13.3	Unknown or blank

C. Emergency Decision Making

Q C-1 Who has the legal authority to activate an emergency warning or public alert system in your community? (%)

66.9	Identified name and position
5.9	Identified position and organization
23.5	Identified position only
2.2	Identified organization only
1.5	Unknown or blank

Q C-2 Does anyone in the community have the assigned responsibility to make the decision to warn the public in the event of a chemical accident? (%)

7.4	No
79.4	Yes; same as the person(s) with legal authority in previous question
13	Yes; different than the person(s) with legal authority in previous question

Q C-3 Please describe the process for making the decision to warn the public after receiving an initial alert from the facility? (%)

5.9	No procedure described
63.2	Vague procedure
31.6	Clear SOP

Q C-4 Many different types of emergencies can occur at a chemical facility. One type is a very fast release of hazardous materials posing a clear threat to public safety. A second type is a slowly developing problem with a potential for a release.

a. What is the minimum number of people that would have to be involved in making the decision to warn the public?

Mean = 2.2 people in a fast-moving emergency

Mean = 4.6 people in a slowly developing emergency

Q C-5 Once you have received an initial alert from the facility, about how long would it take to <u>mobilize the necessary people</u> that make the decision once an initial alert is received and what is the basis for your estimate?

In a fast-moving emergency:

Minimum: mean = 8.5 min Most likely: mean = 15.0 min

In a slowly developing emergency:

Minimum: mean = 61.6 min Most likely: mean = 71.5 min

Basis for estimate:

7.3	Not described
72.3	Professional judgment
4.4	Exercise and drills
6.6	Routine experience
8.8	Previous disaster

Q C-6 Is there a written procedure for making the decision to issue a public warning? (%)

61.8	No or blank
39.0	Yes; please attach a copy of the procedure

Q C-7 How long would it take to <u>make a decision</u> to notify the public? (Please estimate the range as a minimum and most likely time in hours -H and minutes -M; if less than 1 hour write a 0 before the H and specify minutes only)

In a fast-moving emergency:

Minimum: mean = 9.9 min Most likely: mean = 15.3 min

In a slowly developing emergency:

Minimum: mean = 23.3 min Most likely: mean = 31.0 min

Q C-8 There are a number of ways to protect the health and safety of people from a release of hazardous chemicals (protective actions).

a. What protective actions would be considered for recommendation in a chemical emergency for the <u>general population</u>? (%)

8.0	None mentioned
1.5	To be developed
32.1	Evacuation only
4.4	Shelter only
0.0	Enhanced shelter only
43.8	Evacuation and shelter
10.2	Evacuation and enhanced shelter

b. What protective actions would be considered for recommendation in a chemical emergency for institutional facilities (such as hospitals, schools, prisons, or nursing homes)? (%)

10.9 None mentioned
0.7 To be developed
26.3 Evacuation only
9.5 Shelter only
0.7 Enhanced shelter only
32.8 Evacuation and shelter
16.8 Evacuation and enhanced shelter

Q C-9 Does your community have a written procedure for making a decision about what protective actions to recommend or order? (%)

69.8 No or blank
30.9 Yes; please attach a copy of the procedure

Q C-10 Does your community have a written plan or procedure for issuing an alert/warning? (%)

35.3 No or blank
65.4 Yes; please attach a copy of the procedure

Q C-11 Does your community have a written warning/alert plan or procedure that is specific to the facility? (%)

86.0 No or blank
14.7 Yes; please attach a copy of the procedure

Q C-12 What effort, if any, has your community made to provide the general public with information about chemical hazards and emergency response? (%)

Efforts

23.5 None or blank
16.9 None but recognize need
11.8 Program being developed
8.1 Vague description of program
21.3 Single activity described
19.1 Multiple activities described

Relevance

2.9 General program
52.2 Specific reference to chemical hazard
30.9 Cannot determine if it is specific to chemical hazard

Sample material

14.7 Provided actual material

D. Populations at Risk

Q D-1 About what percentage of the land use within 1 mile of the facility is in the following categories?

Mean percent

31% Open space
22% Industrial (wholesale; manufacturing)
10% Commercial (retail; offices)
21% Suburban residential (single family)
8% Urban residential (multi-family)
2% Other

Q D-2 About what percentage of the land use within 5 miles of the facility is in the following categories?

Mean percent

31% Open space
14% Industrial (wholesale; manufacturing)
12% Commercial (retail; offices)
29% Suburban residential (single family)
10% Urban residential (multi-family)
2% Other

Q D-3 Approximately how many people live within 1 mile of the facility?

Mean = 4,368 people

Q D-4 Approximately how many people live within 5 miles of the facility?

Mean = 42,583 people

Q D-5 Are there significant fluctuations in the size of the population (such as workers, tourists, or visitors) in any of the area within 5 miles of the facility?

a. During the day or night? (%)

50.0 No
50.0 Yes

b. During different seasons? (%)

83.8 No
15.4 Yes

c. During weekends? (%)

69.9 No
29.4 Yes

Q D-6 Are there institutional populations within 5 miles of the facility (e.g., schools, hospitals, nursing homes, correctional facilities)?

Type	% with type	Mean number in communities where they are reported
Day care	12.4	6
Schools	64.2	12
Universities	10.2	2
Hospitals	40.9	2
Nursing homes	44.5	3
Correctional facilities	24.8	1

E. Public Alert and Warning

Q E-1 Please indicate the primary and secondary methods, if any, for warning the following populations within 5 miles of the facility. Primary methods are those systems that are most likely to be used in an emergency. Secondary methods are backup options that are currently available for use if primary methods fail.

1 mile (%)

4.4 None
16.1 Door to door/route alert
29.2 EBS/media
10.9 Sirens
22.5 Sirens and EBS/media
3.6 Sirens and tone alerts
8.0 Sirens, tone alerts, and EBS/media
5.8 Other

5 miles (%)

4.4	None
16.1	Door to door/route alert
32.1	EBS/media
8.0	Sirens
20.4	Sirens and EBS/media
2.9	Sirens and tone alerts
5.8	Sirens, tone alerts, and EBS/media
1.2	Other

Institutions (%)

11.6	None
8.0	Door to door/route alert
23.4	EBS/media
9.5	Sirens
10.9	Sirens and EBS/media
2.9	Sirens and tone alerts
6.6	Sirens, tone alerts, and EBS/media
8.8	Tone alerts
18.2	Other

Transients (%)

18.4	None
12.4	Door to door/route alert
35.0	EBS/media
11.7	Sirens
10.9	Sirens and EBS/media
0.7	Sirens and tone alerts
1.5	Sirens, tone alerts, and EBS/media
9.5	Other (predominantly route alert with various other)

Q E-2 How often are the warning equipment and procedures routinely tested? (%)

10.3	Yearly
8.8	Semiannually
25.7	Monthly
31.6	Weekly
13.2	Daily
9.6	Never or blank

Q E-3 Is there a special warning system(s) in your community for another type of hazard (e.g., civil defense outdoor sirens, nuclear power plant system, flash flood warning system) (%)

46.3	No or blank
53.7	Yes
26.5	Civil defense sirens

8.1 Nuclear power plant
5.1 Flash flood
25.7 Other (mainly sirens without specifying a hazard)

Q E-4 Please estimate how long it would take to notify each population group and briefly describe the basis for that estimate.

a. Residents within 1 mile of facility:

Mean = 30.7 min 30.7% unknown

Basis for estimate:

36.5 Not described
44.5 Professional judgment
8.0 Exercises and drills
3.6 Routine experience
8.0 Previous disaster

b. Residents within 1 to 5 miles of facility:

Mean = 34.7 min 43.8% unknown

Basis for estimate:

48.9 Not described
42.3 Professional judgment
5.8 Exercises and drills
0.7 Routine experience
2.9 Previous disaster

c. Institutional populations listed in question D-6:

Mean = ___ min 22.6% unknown

Basis for estimate:

40.1 Not described
50.4 Professional judgment
6.6 Exercises and drills
2.2 Routine experience
1.5 Previous disaster

d. Fluctuating (transient) populations listed in question D-5:

Mean = ___ min 29.9 % unknown

Basis for estimate:

74.5	Not described
23.4	Professional judgment
1.5	Exercises and drills
1.5	Routine experience
0.0	Previous disaster

F. Warning Content

Q F-1 Which of the following authorities (or equivalents) would be identified in the warning as the source of the warning information ? (%)

52.9	Mayor
40.4	County executive
83.1	Civil Defense or emergency official
30.9	City or county manager
26.5	Public health official
22.1	Engineer/scientist from facility
7.4	Engineer/scientist from government
59.6	Police chief
46.3	Sheriff
73.5	Fire chief
47.1	Chemical facility manager
27.9	State official
2.9	No one would be identified
9.6	Other

Groupings (%)

2.2	None
18.2	Only emergency managers or administrators, but not both
40.1	Both emergency mangers and administrators
2.9	Technical experts and emergency managers or administrators
24.8	At least one of each
11.7	More than one of each

Q F-2 Do you have a written message protocol (e.g., EBS messages) for communicating with the general public in an emergency? (%)

66.9	No or blank
33.1	Yes

Q F-3 Do you have a written message protocol (e.g., EBS messages) for communicating with the institutional facilities in an emergency? (%)

80.1	No
19.9	Yes

Q F-4 Do you have warning messages for non-English-speaking populations? (%)

14.0 Yes
41.2 No, do not have non-English-speaking population(s).
44.9 No, have not developed.

G. Coordination

Q G-1 How has your community's emergency organization coordinated emergency planning for a chemical accident with each of the following agencies/organizations in the past several years?

	Does not apply in this community	No contact at all	Initial introductory contact only or missing	Developed emergency response plans with	Ongoing coordinated emergency effort	Participate in emergency exercises with
Chemical facility	0	5.9	27.7	2.9	14.0	50.0
Other local agencies	0	2.2	13.1	5.1	13.2	66.9
State civil defense	0	5.1	9.5	6.6	11.8	67.9
State police	3.2	8.1	16.8	6.6	14.7	52.2
Other communities	0	5.9	20.4	5.9	20.6	47.8
FEMA	0.7	11.8	24.1	8.1	22.1	33.8
Hospitals	1.5	3.7	12.4	7.4	11.0	64.7
U.S. EPA	2.2	27.2	38.0	6.6	11.0	15.4
Media	0.7	6.6	17.5	3.7	14.0	58.1

Q G-2 How many times in the last 2 years have you participated in emergency exercises on chemical accidents?

Median = 2 exercises
(19.9% had 0)

Q G-3 Has your community used information from the Chemical Manufacturers Association CAER Program (Community Awareness/Emergency Response)? (%)

67.6 Yes
33.1 No or blank

Q G-4 What entity has the state designated as the local emergency planning district in your area to develop an emergency plan for chemical accidents? (%)

10.3	City
1.5	Multi-city
61.8	County
9.6	Regional
4.4	State
4.4	Other
7.4	Not specified

Q G-5 Has the membership of this committee been appointed? (%)

12.5	No or blank
88.2	Yes; if yes, how is your community represented on this committee?
78.7	Represented
7.4	Not represented
14.7	Representation not specified

Q G-6 Has the facility provided the community with information describing the hazardous chemicals used at the facility?

18.4	No
80.1	Yes; if yes, what have they provided?

H. Computer Use

Q H-1 Does your community use a computer in emergency planning, that is, in preparing for an emergency? (%)

52.9	No
47.1	Yes

Q H-2 Does your community use a computer in emergency management, that is, in responding to an emergency? (%)

61.8	No
37.5	Yes

31.4	Use for both
15.3	Use for planning only
5.8	Use for management only

Q H-5 If you use software designed specifically for emergency planning functions, please describe the programs and their use. (%)

41.9	Not applicable
35.3	Do not use
23.5	Use

Q H-6 If you use software designed specifically for emergency management functions, please describe the programs and their use. (%)

39.7 Not applicable
40.4 Do not use
20.6 Use

Q H-7 Do you use a model for predicting the dispersion of chemicals? (%)

89.0 No or blank
11.8 Yes

I. Overall Assessment

Q I-1 What do you consider to be the weakest link in the sequence of tasks that are involved in getting a timely and effective warning to the public around the chemical facility? (%)

43.8 Problems in disseminating alert and notification to the public
24.1 Timely release of information from the facility
10.9 Communication problems within the community organization
10.2 Poor public response to warning
6.6 Cooperation from the facility
5.1 Communication problems with the facility
4.4 Lack of planning
2.2 Lack of training
2.2 No weak links
1.5 Feasibility of public protection
1.5 Problems in warning special populations
19.0 Other

Q I-2 Overall, what is your assessment of the capability to provide a timely warning to the public within 5 miles of the facility in the event of a serious emergency? (%)

25.7 It is highly certain that an effective warning would be made
48.5 It is somewhat certain that an effective warning would be made
19.9 It is somewhat uncertain that an effective warning would be made
5.1 It is highly uncertain that an effective warning would be made

Q I-3 Are there other facilities in your community that require emergency plans because they have hazardous chemicals? (%)

5.1 No
94.1 Yes; if yes, about how many facilities?

Mean = 142 facilities in the community

Q I-4 On the whole how do the emergency planning efforts of the facility identified in the cover letter compare to the other chemical facilities in your community? (%)

19.9 Much better than others
19.9 Somewhat better than others
40.4 About the same as others
1.5 Somewhat poorer than others
5.1 Much poorer than others

Q I-5 If an emergency occurred at the facility, how does the community's ability to issue a timely warning to the public around the facility compare with the ability to issue a warning around other facilities? (%)

13.2 Significantly better than for others
11.8 Slightly better than for others
61.8 About the same as for others
2.9 Slightly poorer than for others
2.2 Significantly poorer than for others

Q I-6 The following are areas in which the acquisition of new resources or improvements of existing capabilities could enhance preparedness for chemical emergencies in your community. If you could obtain these over the next several years, which would you want first, second, third, and so forth? Please rank these areas in the order which you feel they are needed by your community.

Mean rank

3.7 Public alert/warning equipment
4.1 Communications equipment
4.7 Computer with emergency management system
5.1 Protective clothing
5.5 Monitoring equipment
5.4 Funding for sending staff to training
5.7 Funding for a planner
5.9 Respiratory protection equipment
6.2 Funding to prepare an emergency plan
6.7 Decontamination equipment
7.2 Medical equipment

Q I-7 Advances in knowledge and technology can improve the basis for emergency preparedness. The following are areas in which improvements could enhance preparedness for chemical emergencies. If you could obtain these over the next several years, which would you want first, second, third, and so forth? Please rank these areas in the order which you feel they are needed by your community.

Mean rank

3.5	Improve public alert/warning technologies
4.4	Improve communications technologies
5.3	Improve knowledge on protective action effectiveness
5.4	Improve training programs/courses
5.5	Improve knowledge on the toxicity of chemicals
5.6	Improve monitoring technologies
5.7	Improve computerized dispersion models
6.0	Improve protective equipment
6.3	Improve decision support systems
6.3	Improve information hot-lines
7.0	Improve technical planning guides

Q I-8 Has any emergency occurred in the last 5 years that has resulted in a public warning in your community? (%)

39.0	No
61.0	Yes

How many people in total assisted in answering this questionnaire?

Mean = 2.4 people

About how long did it take to complete?

Mean = 4.5 hours

Table A-1. Primary warning technologies (% of communities)

	Public within 1 mile of facility	Public 1 to 5 miles from facility	Institutional facilities within 5 miles	Transient populations
Permanent sirens	43.4	39.0	27.9	22.8
Tone-alert radio	12.5	11.8	19.9	4.4
Telephone ringdown system	2.2	3.7	10.3	1.5
Fixed loudspeakers/ public address	10.3	10.3	10.3	5.1
Emergency broadcast system	48.5	52.9	35.3	34.6
Door to door	30.1	19.9	17.6	7.4
Portable sirens/ loudspeakers on vehicles	50.0	43.4	22.1	36.0
Television/radio	44.1	49.3	35.3	36.8
Cable override	20.6	22.1	13.2	10.3
Commercial telephone	14.0	10.3	38.2	4.4
Two-way radio	10.3	10.3	12.5	3.7
Airplane or helicopter	3.7	3.7	2.2	2.2
Other	1.5	1.5	1.5	4.4

Table A-2. Secondary warning technologies (% of communities)

	Public within 1 mile of facility	Public 1 to 5 miles from facility	Institutional facilities within 5 miles	Transient populations
Permanent sirens	2.2	3.7	3.7	6.6
Tone-alert radio	3.7	2.2	3.7	1.5
Telephone ringdown system	2.2	2.2	2.2	1.5
Fixed loudspeakers/ public address	7.4	7.4	6.6	5.1
Emergency broadcast system	20.6	16.9	22.1	11.8
Door to door	48.5	49.5	41.9	26.5
Portable sirens/ loudspeakers on vehicles	36.0	44.1	35.3	26.5
Television/radio	36.0	33.8	30.9	19.9
Cable override	24.3	22.8	19.9	11.0
Commercial telephone	24.3	23.5	19.9	10.3
Two-way radio	13.2	11.8	12.5	5.1
Airplane or helicopter	16.2	16.2	13.2	9.6
Other	1.5	1.5	2.2	0

APPENDIX B

COMMUNITIES PARTICIPATING IN THE STUDY AND THEIR DISTRIBUTION BY SIZE AND GEOGRAPHICAL LOCATION

Table B-1. Geographical distribution of communities

Region	States	Number
1	Conn., Maine, Mass., N. H., R. I., Vt.	2
2	N. J., N. Y.	16
3	Del., Md., Pa., Va., W. Va.	18
4	Ala., Fla., Ga., Ky., Miss., N. C., S. C., Tenn.	20
5	Ill., Ind., Mich., Minn., Ohio, Wis.	23
6	Ark., La., N. M., Okla., Tex.	24
7	Iowa, Kans., Mo., Nebr.	10
8	Colo., Mont., N. Dak., S. Dak., Utah, Wyo.	2
9	Ariz., Calif., Hawaii, Nev.	12
10	Alaska, Idaho, Oreg., Wash.	9

Table B-2. List of communities with completed questionnaire

City	State	Unit	1980 Population
Mobile	Ala.	County	364,000
Columbia	Ark.	County	26,644
Jacksonville	Ark.	City	27,600
Maricopa	Ariz.	County	1,508,000
Anaheim	Calif.	City	221,800
Bakersfield	Calif.	City	105,600
Brisbane	Calif.	City	3,000
El Segundo	Calif.	City	13,800
Humboldt	Calif.	County	1,080,000
Oakland	Calif.	City	339,300
Orange	Calif.	County	1,931,500
Riverside	Calif.	County	663,900
San Jose	Calif.	City	636,600
South Gate	Calif.	City	66,800
Yolo	Calif.	County	113,400
New Castle	Del.	County	399,000
Gulf	Fla.	County	10,700
Santa Rosa	Fla.	County	56,000
Tampa	Fla.	City	271,500
Brunswick	Ga.	City	17,600
Dalton	Ga.	City	20,700
Fulton	Ga.	County	590,000
Richmond	Ga.	County	181,600
Smyrna	Ga.	City	20,300
Benton	Iowa	County	23,600
Clinton	Iowa	County	57,100
Des Moines	Iowa	County	46,200
Story	Iowa	County	72,300
Woodbury	Iowa	County	100,884
Bannock	Idaho	County	65,400
Madison	Ill.	County	247,700
Marshall	Ill.	County	14,500
North Chicago	Ill.	City	38,800
Will	Ill.	County	324,500
Delaware	Ind.	County	128,600
Posey	Ind.	County	25,400
Johnson	Kans.	County	270,300
Sedgwick	Kans.	County	366,500
Wyandotte	Kans.	County	172,300
Ballard	Ky.	County	8,800
Hardin	Ky.	County	88,900
Marshall	Ky.	County	25,600
McCracken	Ky.	County	61,300
Ascension	La.	County	50,100
Baton Rouge	La.	City	219,500
Convent	La.		

Table B-2. Continued

City	State	Unit	1980 Population
St. Charles Parish	La.	County	37,500
Danvers	Mass.	City	26,200
Baltimore	Md.	City	786,700
Bay	Mich.	County	119,900
Benton Harbor	Mich.	City	14,700
Grand Haven	Mich.	City	11,800
Kalamazoo	Mich.	County	212,400
Manistee	Mich.	County	23,000
Marquette	Mich.	County	74,100
Marysville	Mich.	City	7,300
Oakland	Mich.	County	1,011,800
Rosemount	Minn.	City	5,100
Duson	Mo.	City	
Jackson	Miss.	County	118,000
Warren	Miss.	County	51,600
Yellowstone	Mont.	County	108,000
Pitt	N.C.	County	83,700
Beatrice	Nebr.	City	12,900
Elizabeth	N.J.	City	106,200
Gibbstown	N.J.	City	5,700
Little Falls	N.J.	City	11,700
Mt. Holly	N.J.	City	10,800
Salem	N.J.	County	64,700
Somerset	N.J.	County	203,100
Union	N.J.	County	504,100
Wayne	N.J.	City	49,100
West Caldwell	N.J.	City	11,407
Henderson	Nev.	City	24,400
Chautauqua	N.Y.	County	146,900
Delaware	N.Y.	County	46,900
Lewis	N.Y.	County	25,000
Newburgh	N.Y.	City	23,400
Rensselaer	N.Y.	County	152,000
Utica	N.Y.	City	75,600
Waterloo	N.Y.	City	5,300
Allen	Ohio	County	112,200
Fairfield	Ohio	County	93,700
Hamilton	Ohio	County	873,100
Solon	Ohio	City	14,300
Stark	Ohio	County	378,800
Toledo	Ohio	City	354,600
Enid	Okla.	City	50,400
Muskogee	Okla.	City	40,000
Osage	Okla.	County	39,300
Rogers	Okla.	County	46,400
Woodward	Okla.	County	21,200

Table B-2. Continued

City	State	Unit	1980 Population
Portland	Oreg.	City	366,400
Berks	Pa.	County	312,500
Blair	Pa.	County	136,600
Bucks	Pa.	County	479,200
Carbon	Pa.	County	53,285
Philadelphia	Pa.	City	1,688,200
Somerset	Pa.	County	81,200
Providence	R.I.	City	156,800
Kershaw	S.C.	County	39,000
York	S.C.	County	106,700
Baytown	Tenn.	City	
Sharon	Tenn.	City	1,100
Sullivan	Tenn.	County	144,000
Beaumont	Tex.	City	118,100
Brazoria	Tex.	County	169,600
Calhoun	Tex.	County	19,600
Dallas	Tex.	City	904,000
Dimmitt	Tex.	City	11,400
Dumas	Tex.	City	12,200
Ector	Tex.	County	115,400
Houston	Tex.	City	1,594,100
Hutchinson	Tex.	County	26,300
Orange	Tex.	County	83,800
Pasadena	Tex.	City	112,600
Port Arthur	Tex.	City	61,200
Texas City	Tex.	City	41,400
Hopewell	Va.	City	23,400
Portsmouth	Va.	City	104,600
York	Va.	County	35,500
Camas	Wash.	City	5,700
Cowlitz	Wash.	County	79,600
Skagit	Wash.	County	64,200
Snohomish	Wash.	County	337,000
Spokane	Wash.	City	341,800
Walla Walla	Wash.	County	47,500
Whatcom	Wash.	County	106,700
Brown	Wis.	County	175,300
Madison	Wis.	City	170,600
Oneida	Wis.	County	31,200
Marinette	Wis.	City	12,000
Kanawha	W. Va.	County	231,400
Marshall	W. Va.	County	41,600
Putnam	W. Va.	County	38,200
Laramie	Wyo.	County	68,600

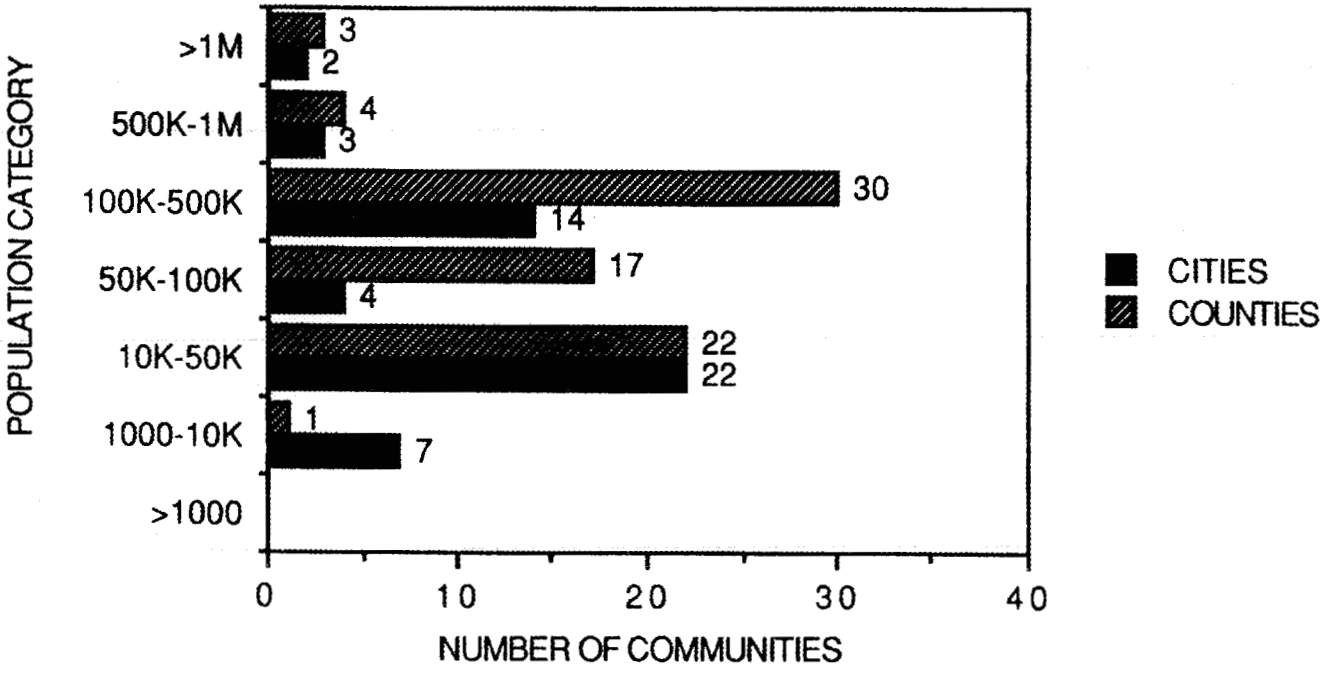

Fig. B-1. Distribution of sample communities.

APPENDIX C

DATA FROM THE FACILITY QUESTIONNAIRES ON PUBLIC ALERT AND NOTIFICATION

(N = 134)

Table C-1. Primary communications equipment used to notify the community of a chemical accident

Communication method	Facility response (%)
Commercial telephone	43.3
Two-way radio	9.0
Dedicaated telephone	9.7
Dedicated radio	6.0
Pager	0.
Sirens	3.7
In person	3.0
PA/loudspeakers	0.
Alarm system	3.7
911	13.4

Clarity of Interaction

C-1. Identification of designated official responsibility for receiving an alert from the chemical facility. (%)

1.5	Identified name and position
9.0	Identified position and organization
5.2	Identified position only
60.4	Identified organization only
23.8	Did not identify

C-2. Identification of designated official responsibility for sending an alert from the chemical facility. (%)

93.3	Identified by title
6.7	Not identified

C-3. Identification of designated backup official responsible for sending an alert from the chemical facility. (%)

50	Identified by title
50	Not identified

C-4. Identification of off-hour alert responsibility. (%)

48.5	Same
3.7	Different, not specified
35.8	Different, specified
12.0	No response

C-5. How has your facility's emergency organization coordinated with each of the following agencies/organizations in the past several years? (%)

Circle letter of those that exist in	No coordination at all your area	Initial/ introductory contact	Developed emergency response plans only	Ongoing coordinated emergency effort with	Participin emergency exercises with
Local fire	0	14.9	9.0	25.4	44.8
Other internal facility org.	11.2	3.0	4.5	20.9	34.4
Local/county police	5.2	23.1	11.2	20.5	30.6
Local civil defense	10.4	16.4	7.5	22.4	33.6
State police	32.8	17.2	3.0	12.7	20.9
Industry mutual aid association	20.9	8.2	6.7	16.4	27.6
Hospital emergency rooms	11.5	23.9	13.4	17.9	23.1
State emergency	20.5	29.9	9.0	9.0	11.2
State EPA	11.7	26.9	13.4	28.7	8.2

Number of exercises within past 2 years:

Group	Mean number of exercises
Local fire	2.0
Other internal facility organization	6.2
Local/county police	1.2
Local civil defense	2.3
State police	0.9
Industry mutual aid association	2.5
Hospital emergency rooms	0.8
State emergency	0.5
State EPA	0.4

Table C-2. Clarity of emergency procedures

Type procedure	Status (%)		
	None	Vague	Clear/SOP
Decision making	8.2	56.0	33.6
Communication	9.7	53.0	33.6

C-6. Overall assessment of the capability to provide a timely warning to the public within 5 miles of the facility in the event of a serious emergency. (%)

82.1	It is highly certain that an effective warning would be made
12.7	It is somewhat certain that an effective warning would be made
0.7	It is somewhat uncertain that an effective warning would be made
0	It is highly uncertain that an effective warning would be made
4.5	Missing

C-7. Weakest link in the sequence of tasks that are involved in getting a timely and effective warning to the public around the chemical facility. (%)

35.1	Problems in disseminating alert and notification to the public
20.1	No weak links
14.2	Size of population or area at risk
6.7	Communication problems between the facility and the community
3.7	Communication problems within facility
3.7	Lack of planning
1.5	Feasibility of public protection
3.0	Cooperation from the community
0.7	Lack of training
4.5	Communication problems within the community
0.7	Monitoring detection
0.7	Problems in warning special populations
13.4	Other

APPENDIX D

WARNING SYSTEMS REFERENCES AND BIBLIOGRAPHY

WARNING SYSTEM REFERENCES AND BIBLIOGRAPHY

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