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Protective Action Decision Guide

for Emergency Services during
Outdoor Hazardous Atmospheres



Shelter-in-Place Report
Issued by the Metropolitan Fire and Emergency Services Board

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Guide Definitions

ACH	Air Changes per Hour
AEGL	Acute Exposure Guideline Level
AIHA	American Industrial Hygiene Association
ALOHA	Areal Locations of Hazardous Atmospheres
CALD	Cultural and Linguistically Diverse Groups
CFA	Country Fire Authority
CSEPP	Chemical Stockpile Emergency Preparedness Program
Concentration	Concentration is the amount measured in parts per million (ppm) or milligram per cubic metre (mg/m ³), of a substance present in the atmosphere resulting from a release.
DH	Department of Health
ERPG(s)	Emergency Response Planning Guideline(s). Values intended to provide estimates of concentration ranges above which one could reasonably anticipate observing adverse health effects.
USEPA	United States Environmental Protection Agency
Evacuation	Evacuation is the timely and effective relocation of exposed persons or persons having the potential of being exposed to a toxic or chemical agent, to an alternate location having no potential for exposure to the same toxic or chemical agent.
Incident Controller	An incident controller is the person in charge of the overall incident management at site.
NEWS	National Emergency Warning System
NOHSC	National Occupational Health and Safety Commission
Protective Action Zones	This is the area downwind from the release point within which the airborne concentration of the vapour is high enough to necessitate a protective action.
SEWS	Standard Emergency Warning Signal
SIP	Shelter-in-place, is a protective action to provide public safety by going indoors and following the recommended shelter, shut and listen actions as instructed by the first responders.
STEL	Short Term Exposure Limit, 15 minute occupational exposure limit
Toxic	A substance that is poisonous and/or hazardous to life or health
TWA	Time-weighted average, 8 hour Occupational Exposure Limit

Summary

This guide provides information to emergency planners on Best Practice principles for planning and implementing community protective actions during potential airborne hazards caused by industrial or transport accidents, chemical/biological/radiological (CBR) events, or structure fires. The guide is designed to be used as an emergency pre-planning tool for incident controllers and provides reference material for fast protective action decision making during outdoor hazardous atmospheres. A more comprehensive report on protective action decision making is available for further information.

The key points covered in this guide are:

1. Shelter-in-place (SIP) is an effective public protective action when prompt response and actions are implemented before a hazardous plume arrives.
2. When to terminate SIP is important for reducing community exposure.
3. Evacuation would be issued only for a predicted long term release (e.g. duration >4 hrs) or if a flammable atmosphere is expected/detected. Evacuation of residents may take up to 2 hrs. It is critical that the community is evacuated before the plume arrives, and in most cases a delay in ordering an evacuation will provide greater risks to the community.
4. How to prepare a SIP strategy, including decision tools and key points to consider during outdoor hazardous atmospheres.
5. Guidance on initiating, maintaining and ending SIP in the form of a flow chart and considerations table.

1. Introduction

1.1 Purpose

To provide emergency services with a standard approach to community protective actions during a chemical incident or fire, being accidental or deliberate, by providing a strategy for incident controllers to follow. This includes advice on how and when to initiate and terminate SIP protective actions.

1.2 Shelter-in-Place

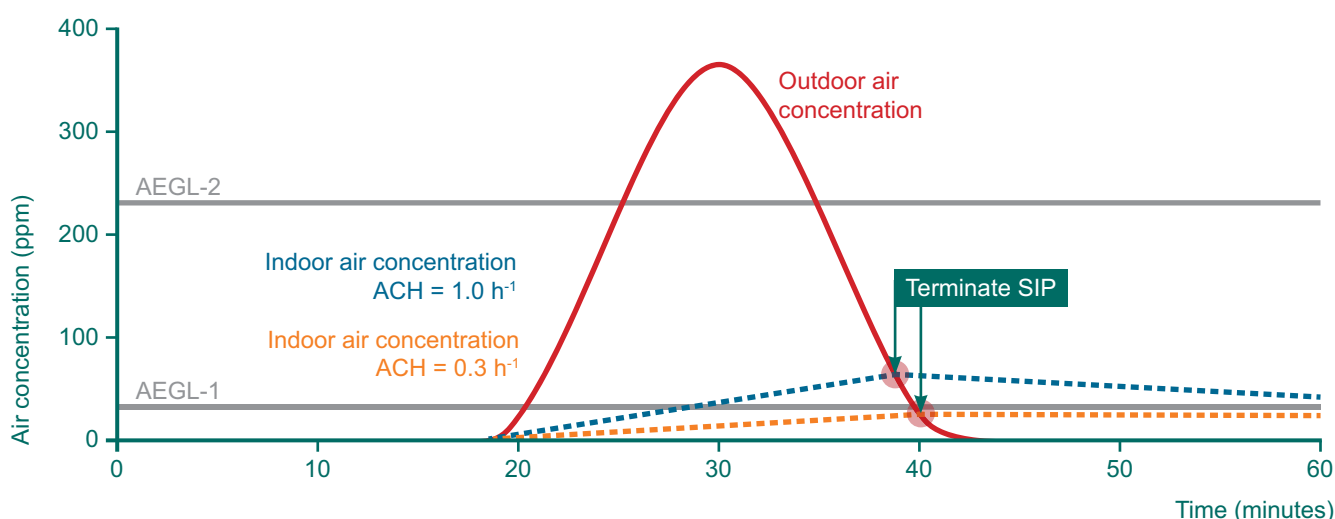
SIP has shown worldwide to be an effective emergency response action during short-term chemical release situations when the outdoor atmosphere is too toxic for evacuation.

The SIP action requires the public to take shelter indoors and seal the building. The air inside a building provides temporary protection until the vapour cloud has passed. The level of protection provided by residential buildings varies with the rate at which outdoor air enters the building (e.g. how leaky the structure is). Recent research has validated the effectiveness of Australian residential houses for short term sheltering during toxic chemical releases, including smoke from fires.

The benefits of temporarily sheltering can be seen in Figure 1. This graph shows estimated indoor air concentrations for two houses with different air exchange rates (0.3 and 1.0 h^{-1}), compared to an outdoor concentration of ammonia over one hour during a hypothetical release. Both houses have significantly lower contaminant air concentrations than outdoors as the plume passes over (i.e. at the peak of the outdoor curve), with the less leaky house ($\text{ACH} = 0.3\text{ h}^{-1}$) providing the greatest level of protection. After the plume has passed, the outdoor concentration quickly drops, and a point is reached where the indoor air concentration equals the outdoor concentration. This time point, where the solid (outdoor air) and dotted (indoor air) lines intersect, is the best time for a person to end SIP. Continuing to SIP past this point would lead to greater exposure because the concentration continues to rise after the peak of the plume has passed, and it also takes a considerable amount of time for the indoor concentration to decrease and re-equilibrate with the outdoor atmosphere.

Educating the public on the importance of prompt action when advised to take shelter, and then when to leave the shelter, is vital for successful public protection.

Figure 1. Computer modelling of airborne concentration of ammonia, outdoors and indoors at a point 2 km downwind for two building air exchange rates



1.2.1 Variations in Protection for Shelter-in-Place

The level of protection provided by a shelter varies from building to building depending on the number of cracks and openings that allow outside air into the building. This rate of airflow is known as the air exchange rate, and is a measure of the number of times fresh air replaces the indoor air in one hour. In a recent study of air exchange rate on a variety of house types, a clear trend appears that older homes are significantly more leaky (Figure 2). This can be explained by changes in construction materials and techniques that were required by new building regulations introduced in the early 1980s, to reduce energy consumption. As a consequence newer buildings provide greater protection from outside contaminated air. Renovated houses and weatherisation techniques, such as door and window seals, have been found to dramatically increase the level of protection of buildings.

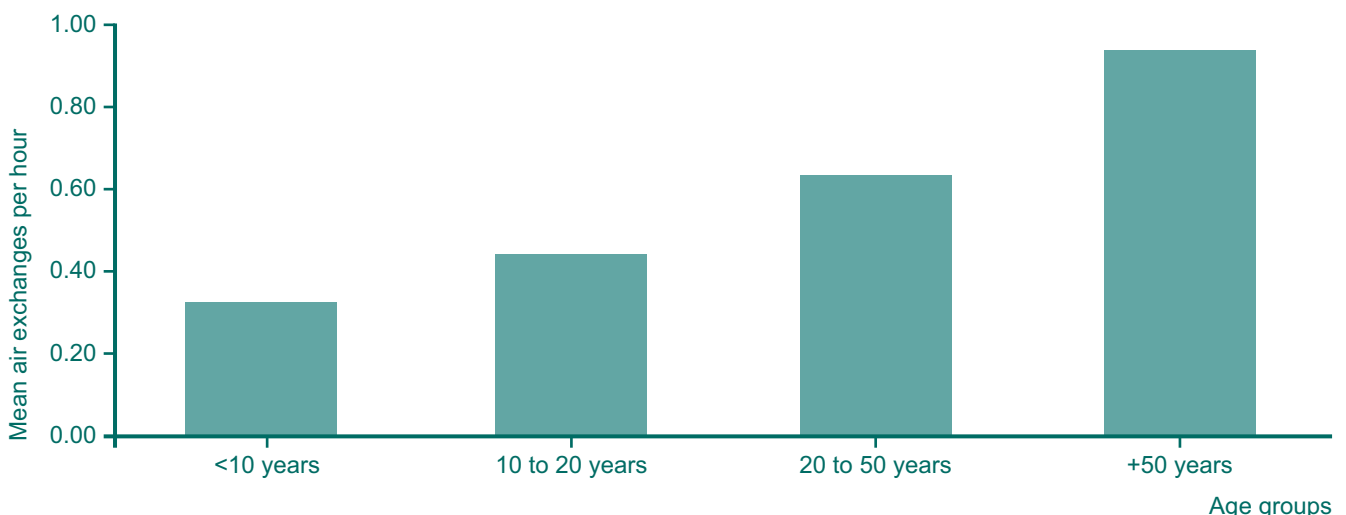
1.2.2 Improving Building Protection

Scientific studies have reported simple short term solutions to reduce the air change rate of buildings. Selecting an interior room for shelter on the downwind side of the house, preferably with no external doors or windows can be effective. Taping gaps under doors and around windows and vents with duct tape further reduces air infiltration into the shelter, this is known as expedient sheltering. In reality many people will not have the materials or capability to implement expedient sheltering.

1.2.3 Limitations of Shelter-in-Place

- SIP provides only a temporary protection for short term chemical releases (up to 4 hours). Sheltering time depends on a number of factors, most importantly, release duration and building air exchange rate.
- Evacuation is the safest option if there is time to do so before the arrival of the hazardous plume.
- Evacuation is preferred if the release duration is predicted to be long (> 4 hrs).
- Time delays for issuing a warning to SIP can reduce the effectiveness of building protection.
- Public awareness and education campaigns are essential for successful compliance with SIP.
- Findings from post chemical incidents studies have reported that there will always be a percentage of the population that will not follow emergency instructions or will act contrary to the direction (i.e. evacuation when instructed to shelter). Emergency pre-planning needs to consider these people.

Figure 2. Mean Air Exchange Rate (h^{-1}) versus Building Age (years)



1.3 Evacuation

Evacuating a population away from a toxic plume is a very effective protective action as it removes the people from hazard. However, due to the unexpected nature of chemical accidents and the limited time to carry out this process, it may lead to higher exposures, unless completed before the arrival of the toxic plume.

There are two types of evacuation: precautionary or responsive.

Precautionary evacuation may be instigated by an incident controller if informed of a potential hazardous material release that has not yet occurred. This type of evacuation may also be issued for a residential area during a chemical release that is not directly affected by the hazardous plume, but there is a possibility of a change in the direction of the plume which may lead to high levels of exposure in this area.

Responsive evacuation involves removing residents away from the area where outdoor air concentrations are expected to exceed community exposure levels. This type of evacuation is very difficult to do as people may be exposed to high outdoor air concentrations during this process. Fire Services may deem this to be a rescue depending on the level of personal protective equipment and respiratory protection required. It is generally safer to advise people to stay in their homes in this situation, to reduce the level of exposure to the public and to the emergency responders.

Both types of evacuation are very resource intensive and require extensive planning, including:

- Estimating the number of potential evacuees, with particular emphasis on populations with special needs,
- Identifying the most appropriate evacuation routes and safe destinations,
- Estimating the time needed for evacuation,
- Establishing Traffic Control Points; and
- Anticipating potential problems.

Consideration needs to be made of the estimated evacuation time as compared to the plume duration time. In most cases the plume duration will be far less than the time it takes to initiate and implement an evacuation, whereby most evacuations take 2 to 4 hours to accomplish successfully.

1.4 Community Exposure Standards

The level of risk to the community varies with the outdoor air chemical concentration and its related health effects. The level of public safety has previously been measured in terms of Occupational Exposure Standards, developed to protect the worker for an 8 hour day, over a working lifetime. These limits, however, do not provide protection for the general public, particularly the sensitive population, including infants, the elderly and people with respiratory diseases.

A hierarchy-based method for selecting air quality reference values that are appropriate for protecting the public from short-term exposure(s) to chemicals in air has been adopted. These values follow three exposure levels: the Acute Exposure Guideline Levels (AEGL's), the Emergency Response Planning Guidelines (ERPG), and the Australian Occupational Exposure Standards (Table 1).

Table 1. Order of selection for short-term community exposure standards

Hierarchy	Air Quality Exposure Standards	Selection Guide
	Acute exposure guideline levels (AEGL's)	Use AEGL's first. Values for 227 chemicals currently available
	Emergency response planning guidelines (ERPG's)	Use ERPG if no AEGL. Values for 136 chemicals available
	Australian occupational exposure standards	Use 8 hr TWA or 15 min. STEL if no AEGL or ERPG available

2. Preparing a Protective Action Plan

Plans should provide for quickly determining the preferred protective actions and the areas expected to be affected, based on information that should be available minutes after the event. In most cases, the preferred protective action response will be to SIP until further information is gathered for the decision making process.

SIP should always be considered as a three-part process:

1. Early notification to the community to go and stay indoors.
2. Frequent instruction of what to do during the incident.
3. Termination of SIP with follow up information.

It is recommended that protective actions are initiated for affected communities where estimated airborne concentrations are predicted to exceed an AEGL-1. These high risk areas are labelled and isolated as protective action zones according to the airborne concentration, and can be determined through computer modelling and atmospheric monitoring.

Specialist advice and support can be provided for predicting areas at risk. These predictions can be done remotely.

Evacuation should be considered for flammable or explosive material due to the potential for vapour ignition and/or vapour explosion, and difficulty in trying to eliminate ignition sources. Sheltering is recommended for releases of a chemical that displays high toxicity and flammability and atmospheric concentrations remain below 10% LEL.

Evacuating the public into a hazardous atmosphere should be avoided where possible as this would be deemed a rescue and would require considerable resources and personal protective equipment.

A protective action table (Table 2) outlines the conditions associated with the three actions.

2.1 Objective of First Responders

The main objective of emergency services is to avoid public exposure to dangerous levels of a hazardous atmosphere by:

- Determining what protective actions are required,
- Determining the areas where protective actions are required,
- Providing warnings and notification to affected residents as well as other agencies,
- Continual assessment of the situation.

Table 2. Protective Action

Protective Action	Conditions
No action	• If outdoor air concentration is believed not to pose any community health risk
Shelter-in-place	• Consider as initial action • Requires early notification to residents • Must include best time to end SIP • Communication to community essential
Evacuation	• If have sufficient time and resources before arrival of the plume (min. 2 hrs) • Consider if release is flammable or explosive • Consider potential for atmospheric exposure during evacuation

2.2 Protective Action Decision Factors

There are a number of factors that must be considered when deciding the appropriate protective action. Evaluation of the factors listed below can help to determine whether to recommend SIP or evacuation. It is usually better to make initial decisions and directions on incomplete information to avoid delays and risk exposure to the community, rather than wait for complete information such as monitoring results.

Chemical Release Characteristics

- Release duration, (short < 1 hr, long > 4 hrs)
- Release amount
- Release type (spill, fire, explosion)
- Toxicity
- Vapour pressure
- Flammable/Explosive

Weather Conditions

- Wind speed and direction
- Predicted wind changes in speed and direction
- Inversion layers

Population Characteristics

- Population distance from release
- Population size and distribution
- Warning/notification system
- Time of day/business hours/evening/late at night
- Predominant building age in affected area
- Vulnerable high risk individuals (older people, people with disabilities, young children)
- Vulnerable groups (schools, hospitals, aged care)
- Cultural and Linguistically Diverse (CALD) groups

Evacuation Considerations

- Road infrastructure/traffic conditions
- Transport
- Available emergency refuge centres

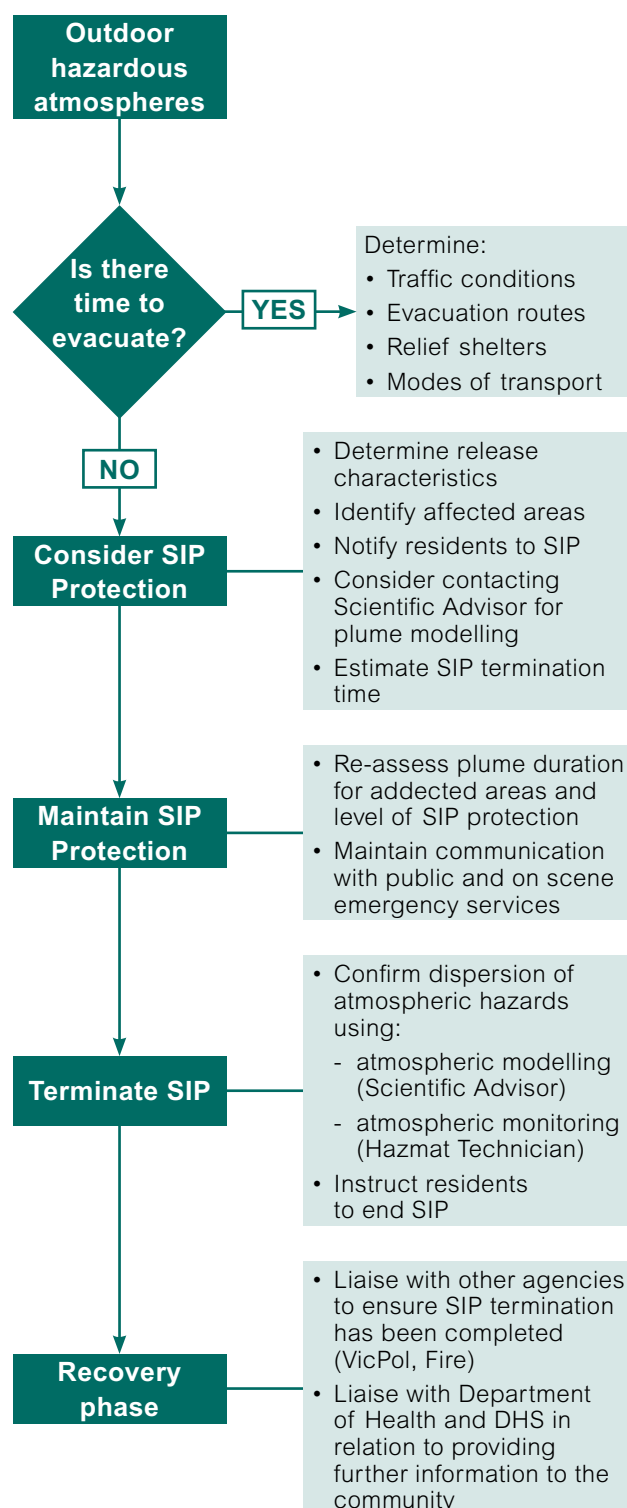
Building Air Exchange Rate (ACH)

- Age of suburb, e.g. new housing estates with houses less than 10 years old will provide longer protection during a chemical plume, compared to suburbs with predominantly older homes such as Victorian weatherboards.

2.3 Decision Tools

Flow charts can be a useful decision tool as they can outline the important factors for determining a protective action in an expedient manner. A flow chart has been developed for incident controllers to use during a chemical release (refer to Figure 3). Specialist advice can be provided to assist in determining atmospheric concentrations using predictive modelling and air quality monitoring.

Figure 3. Protective Action Flow Chart



2.4 Atmospheric Modelling Software

An integrated modelling platform has been developed to assist incident controllers with the decision making process by:

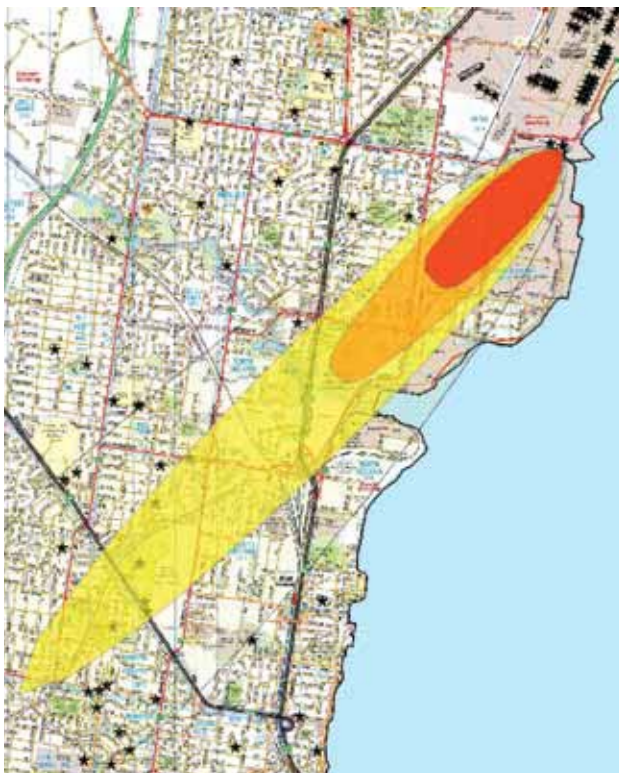
- Identifying affected areas with predicted plume areas and concentrations displayed on mapping systems (refer to Figure 4).
- Identifying the number and type of buildings affected, including features of interest (such as hospitals, schools, day care centres) within the downwind plume.
- Identifying the number of residents affected, including an age breakdown, as well as the number of these working and not working (refer to Figure 4).
- Introducing a new default air exchange rate value into modelling software to

better represent the majority of Australian house types and provide a more accurate estimate of indoor air concentrations.

- Identifying the termination time for SIP, as the time where the outdoor air concentration drops to or below the indoor air concentration.

It should be noted that, at present, plume modelling cannot be used to predict downwind concentrations of products of combustion caused by fires. However, there is a capability in this software to manually highlight an area that is thought to be affected according to the meteorological conditions or from visual or odour observations. This feature will then provide the same report information as the prediction output with additional 'all hazards' capability.

Figure 4. Predicted plume dispersion in three different atmospheric concentrations for a simulated chemical release, and the associated features of interest



Threat zone	Red	Orange	Yellow
Value (ppm)	3000	1200	250
Length downwind (km)	1.2	3.0	7.2
Dwellings			
Semi-detached	6	10	63
Separate house	592	971	3962
Flats	34	98	551
People			
Age 0 - 4	308	410	1298
Age 5 - 14	105	174	579
Age 35 - 44	156	261	1119
Persons working	620	886	4440
Persons not working	779	1184	4233

2.5 Other Considerations

- Transient populations with little or no knowledge of the SIP strategy, e.g. visitors, drivers passing through.
- Consideration for the percentage of the population at risk who will not comply with the recommended protective actions.
- Alternative protective action strategy for special populations who may require additional warning and notification as well as help with the protective actions.
- Non English speaking residents.

2.6 Public Education to Support a Shelter-in-Place Strategy

Evacuation is an instinctive and common response to an emergency situation, however, research has shown that SIP is a proven protective action that is easily understood and accomplished if explained properly and planned for.

SIP community education programs that allow for an understanding and awareness of this protective action are essential for public compliance when official instructions by emergency services are made. SIP protective action messages and terminology used by emergency services must be consistent with the education programs to avoid confusion.

Information templates have been developed for local government and industry to adopt, providing consistent terminology and emergency planning across all sectors.

3. Shelter-in-Place Process

When SIP is chosen as the protective action, its effectiveness follows a three step process.

3.1 Initiating Shelter-in-Place Protection

Prompt public warning is essential for the community to shelter inside their homes before the hazardous plume arrives.

Warnings to the community can be given in emergency situations where public action is required for protection from hazardous airborne contaminants. The incident controller, in collaboration with the police, is responsible for issuing warnings to affected communities and other agencies. Issuing of warnings follows currently established protocols for public emergency communications. The types of warning systems used include:

- Emergency Alert (National Emergency Warning System (NEWS)) – uses telephone infrastructure to broadcast a short pre-recorded message to landlines and mobile phones, informing people of the incident and where to seek further information on what to do.
- Media broadcasters: ABC and commercial radio stations or SKY News TV, where regular programming will be interrupted to broadcast general advice and specific information to the public. Other electronic media will also carry information during special bulletins for major events.
- Standard Emergency Warning Signal (SEWS) is a 5-15 second tone alert for radio and television, to alert the resident of a proceeding emergency message.
- Door knocking by police and other emergency services can be used to notify residents to evacuate if time permits before a chemical plume arrives. You may also want to consider utilising the PA system available in appliances.

Initial Public Advice

An initial SIP instruction should be given as soon as the need for protective action is required, as a result of a chemical release. The emergency broadcast instruction should include the following information:

“Since (time) this morning/afternoon emergency services have been in attendance at an incident at (company name and address).

Residents bounded by the area of (give area and Melways references) are advised to take shelter indoors immediately to avoid outdoor contaminants. Close all exterior doors, windows and vents, and ensure that heating and cooling systems are turned off.

The period of time residents can expect to be affected is approx. (insert number of hours). Listen to local ABC or a commercial radio station, or watch SKY News TV for further updates, as well as the safest time to leave and ventilate your home.”

3.2 Maintaining Shelter-in-Place Protection

Instructions of how to SIP should be repeated at regular intervals during the sheltering period. Residents should also be encouraged to continue sheltering and listen for directions on when and how to end SIP.

Advise residents:

- That the expected time to remain in shelter is likely to be brief (one-half to four hours),
- To shelter in an internal room with the least amount of doors and windows,
- To close all external doors and windows, close blinds and not to use air-conditioning or reverse cycle heating,
- To seal any gaps under doors or around windows and wall vents with towels, blankets or plastic,

- Not to use the phone unless for a lifethreatening situation,
- To continue to listen to the radio, ABC and commercial radio stations, or SKY News TV, for additional information about protective actions to take, and for when and how to end SIP,
- That notification on when to end sheltering will be made.

3.3 Ending Shelter-in-Place Protection

3.3.1 How to Decide When to End Shelter-in-Place

Atmospheric dispersion modelling software can be used to estimate the outdoor downwind air concentration and indoor air concentration. Termination time should be made when the outdoor air concentration becomes less than inside the shelters. The toxic effects of the chemical are compared to the community based exposure standards in the dispersion model.

Specialist advisors can provide estimated termination time for SIP to the Incident Controller, based on community-based exposure standards.

If available, air monitoring should be done in the affected areas to support the modelling estimates in termination decisions.

Consideration should be made for shelters close to the source of release. These areas are more likely to be exposed to dangerous concentrations of the hazardous material and may require termination of SIP at an earlier time than for areas further away.

3.3.2 How to Direct a Termination of Shelter-in-Place

An emergency broadcast via the media with instructions to end SIP using a message that is consistent with previously distributed public education materials (using the exact wording and instruction as advised in these materials). A follow up with the community and other agencies should always be performed to ensure that SIP termination has been completed. Further information should be provided to the residents on where to seek medical support if required, and advice in relation to the specific nature and effects of the chemical released.



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