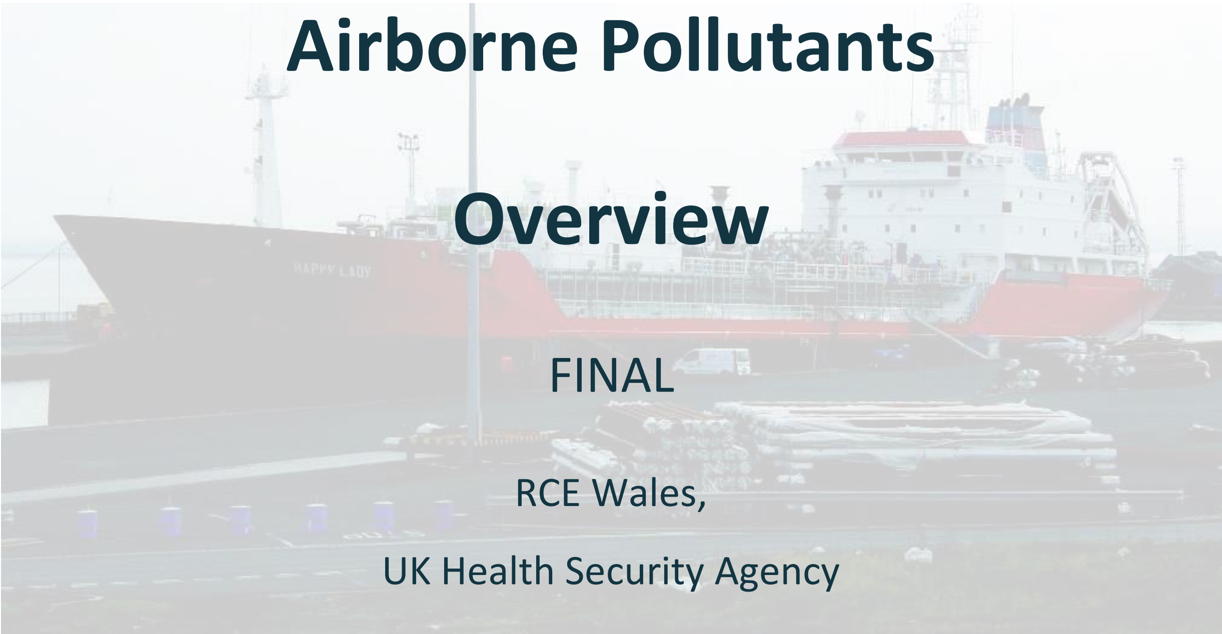
Guidance for Protecting Communities from Maritime Incidents Involving Airborne Pollutants



Overview

FINAL

RCE Wales,

UK Health Security Agency

Co-funded by the European Union Civil Protection

Photographs courtesy UK Health Security Agency

ACKNOWLEDGEMENT

The work described in this report was supported by the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO) of the European Union through the Grant Agreement number 101004912 - MANIFESTS – UCPM-2020-PP-AG, corresponding to the Call objective “Enhancing prevention and protection from the effects of maritime disasters” under priority 1: “Developing response capacity for marine pollution”.

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Project Acronym	**MANIFESTS**
Project Full Title	**MAN**aging risks and **I**mpacts **F**rom **E**vaporating and gaseous **S**ubstances To population **S**afety
Gant Agreement Nr.	**101004912**
Project Website	**https://www.manifests-project.eu/**

Deliverable Nr.	**D3.1**
Status (Final/Draft/Revised)	**Final**
Work Package	**3**
Task Number	**3.2**
Responsible Institute	**CETMAR**
Author/s	**UK Health Security**
Recommended Citation	
Dissemination Level	**Open Source**

Document History			
Version	Date	Modification Introduced	
		Modification Reason	Modified by
01 Draft	January 2022	NA	NA
02 Draft	April 2022	Edits	UKHSA
03 Final	March 2023	Final	UKHSA

EXECUTIVE SUMMARY

- Maritime incidents involving release of gaseous or volatile hazardous and noxious substances (HNS) are rare, but when they do occur, they can have implications for wider communities beyond the incident scene.
- As with any incident, planning and training are key to ensuring effective response and developing an understanding of likely scenarios and the decisions to be made. However, it is not possible to plan for every eventuality and so decisions will often need to be based upon site specific information.
- Protection of wider communities from gaseous or volatile HNS will be essentially between 2 options: Shelter in Place, or Evacuation. Determining the best option will require rapid collection of information, often before detailed modelling or monitoring can be undertaken.
- Key data will include knowledge of the chemical(s) involved, estimates of the scale and likely duration of the incident, weather conditions, and knowledge of the types of receptors that may be impacted. Using these data, it is possible to assess protective options and select the most appropriate (Appendix 1).
- In instantaneous chemical release scenarios, there is a predisposition towards shelter. For prolonged releases over longer durations, sheltering may become less effective. Studies suggest between 2 and 4 hours as the time when this occurs, and decisions should lean towards evacuation. In intermittent release and exposure scenarios it may be possible to shelter for longer periods, with options to ventilate rooms when plumes are not present.
- A number of other factors should also be considered within the decision-making process including feasibility for evacuation, suitability of buildings, susceptible populations and potential imminent risks from explosion or toxicity.
- In all cases prompt clear advice and continued communication to those communities affected is essential.
- All decisions should be reviewed as more data are received.
- The following document (together with accompanying field guide) aim to provide advice for protection of wider communities to such incidents.

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1. INTRODUCTION

Responding to maritime accidents can be especially challenging when involving Hazardous and Noxious Substances (HNS) that behave as gases or evaporators. Due to their potential to form toxic or combustible clouds, evidence-based decisions are needed to protect the crew, responders, the coastal populations and the environment.

MANIFESTS[1] (MANaging risks and Impacts From Evaporating and gaseous Substances To population Safety) aims to improve response capacities to such incidents through the development of innovative decision support tools and operational guidelines and by facilitating access to relevant knowledge, particularly on volatile HNS spills.

The following guidance represents Deliverable D3.2 of Work Package 3 of the MANIFESTS project and was prepared by The UK Health Security Agency RCE Wales (UKHSA) with support from the project consortium.

1.1. Aims of the Guidance

The aim of the guidance is to aid decision making in the immediate aftermath of an incident determining protection measures, prior to receipt of detailed monitoring and modelling data. The guidance is aimed at those involved in managing the initial response as well as those with emergency planning roles.

What **this guidance is not** is a definitive assessment of site and hazard specific risks posed by a particular incident. This will need to be established as information from the scene, local conditions, and ongoing assessment data are collected.

Furthermore, this guidance is targeted at protection of public health and not aimed at the protection of response personnel located within the immediate source of the incident. Other guidance such as The Emergency Response Guidebook[2], installation plans such as those produced under the Seveso Directive, or procedures produced by the response organisation should be used by first responders for this assessment.

[1] MANIFESTS - Home (manifests-project.eu)
[2] Emergency Response Guidebook (ERG) | PHMSA (dot.gov)

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1.2. Background

Hazardous gaseous and volatile substances may be transported, handled and stored in a multitude of forms, including:

- Packaged goods such as cylinders and drums on container ships: a typical cylinder will hold around 25 to 50 kg of pressurized gas,
- Road haulage tanks transported via roll on roll off (RORO) ferries: a road tank may hold around 40,000 litres,
- bulk liquid and gas cargo: a bulk tank may hold around 10,000 m^3 of product.

To manage such potentially dangerous operations, specific regulations have been implemented, via the International Maritime Organisation MARPOL Convention[3], adopting a series of cargo specific codes of practise:

- IMDG Code (International Maritime Dangerous Goods Code) for packaged goods,
- IBC Code (International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk),
- IGC Code (International Gas Carrier Code).

In addition, ports and harbours must also operate to a range of land-based regulations for handling and storage of dangerous goods, such as those set by the EU Seveso Directive[4].

1.2.1 Literature Review

Results of a literature review undertaken by UKHSA[5] as part of this project indicated that while incidents involving gas and volatile HNS are thankfully not prolific, representing less than 1% to 3% of all maritime incidents, they do occur, with many in ports or near the shore, with the potential to impact surrounding communities.

Such impacts were demonstrated from a significant chlorine release in the port of Mumbai in 2007. In this incident, the incorrect storage of cylinders led to a large

[3] International Convention for the Prevention of Pollution from Ships (MARPOL) (imo.org)
[4] Seveso - Major accident hazards - Environment - European Commission (europa.eu)
[5] MANIFESTS - Home (manifests-project.eu)

release of chlorine that affected 120 people including the emergency services, local residents and workers at the port. Seventy people suffered critical injuries.

The review further identified a number of chemicals commonly involved in incidents including ammonia, chlorine and hydrocarbons and indicated in most cases that vapours and gases were heavier than air.

Actual experience of such incidents amongst UK agencies is very limited (see 1.2.2), although incidents have occurred in UK ports and waters. For example, in 2004, The *Coral Arcropora* released 600 kg of Vinyl Chloride at its berth on Manchester Ship Canal with 33 workers and public exposed and required to shelter in nearby buildings to avoid potential exposure risks from toxicity and ignition.

1.2.2 Stakeholder Survey

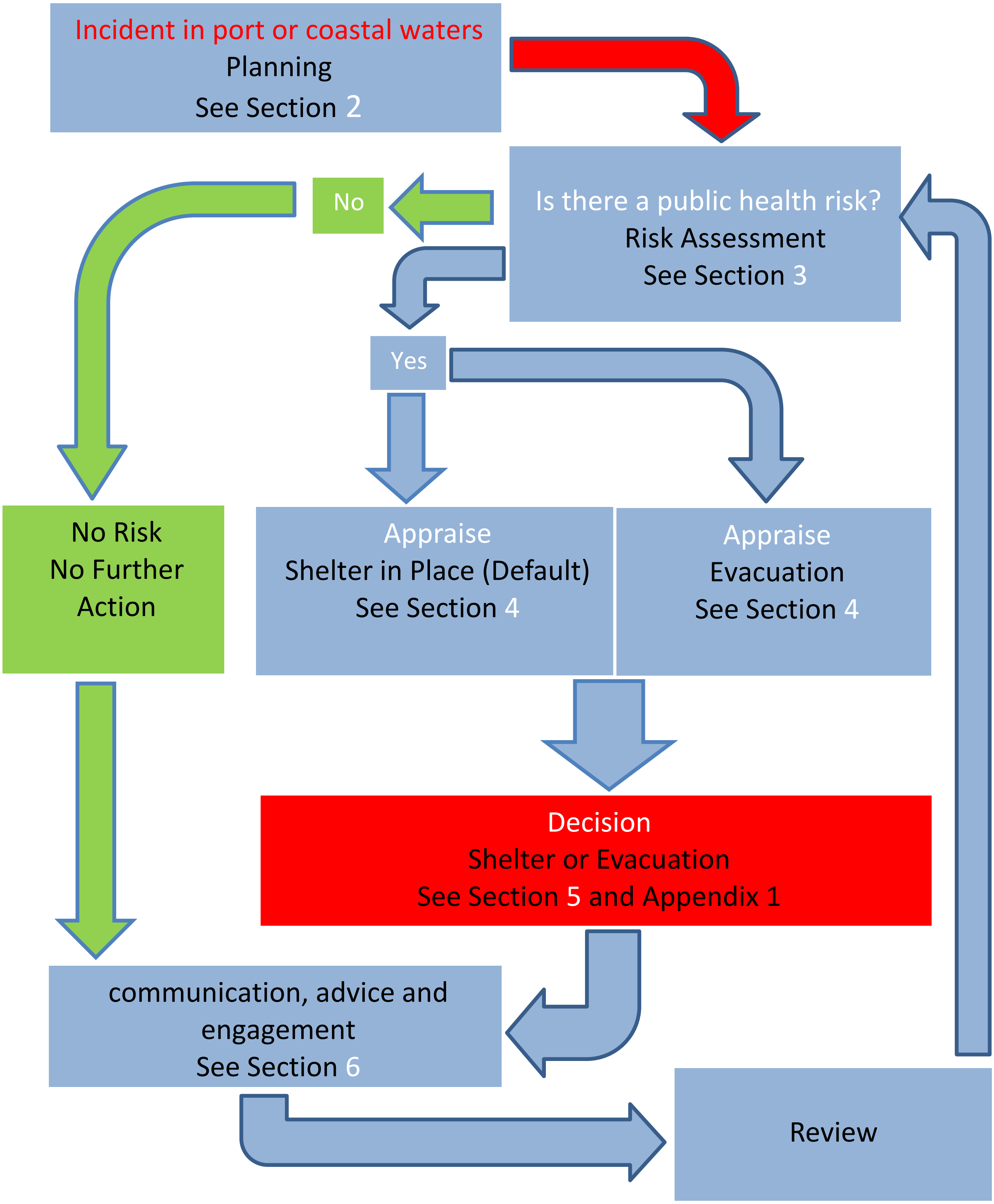
A survey of UK emergency management stakeholders[6] by UKHSA, also as part of this project, noted that while all relevant agencies had plans and procedures for chemical incident response, few were specific to maritime incidents involving airborne releases including events in ports and harbours. Stakeholders identified incident response as a multiagency operation with defined command and control structures and input from a variety of sources. Many relied on third parties to provide modelling and monitoring information typically requiring time for mobilisation and to get meaningful results.

Existing decision-making aids and guidance were identified by stakeholders although again these were not specific to maritime incidents and were more aligned to protection of responders and the immediate incident zone. Based upon these findings UKHSA determined that rapid evidence-based guidance focussing on key HNS and on shoreline and port locations could aid initial decision making for wider community protection until more detailed assessments are made during the response.

The following sections outline key activities for emergency response and provide considerations for determining immediate protective actions for wider communities that may be impacted by gaseous and volatile releases to the atmosphere.

[6] MANIFESTS - Home (manifests-project.eu)

Flow chart illustrating sections in this document



2. INCIDENT RESPONSE

As with any incident or emergency event, maritime incidents involving airborne HNS follow a number of phases. Subsequently incident management can be described as a series of consecutive stages (Figure 1):

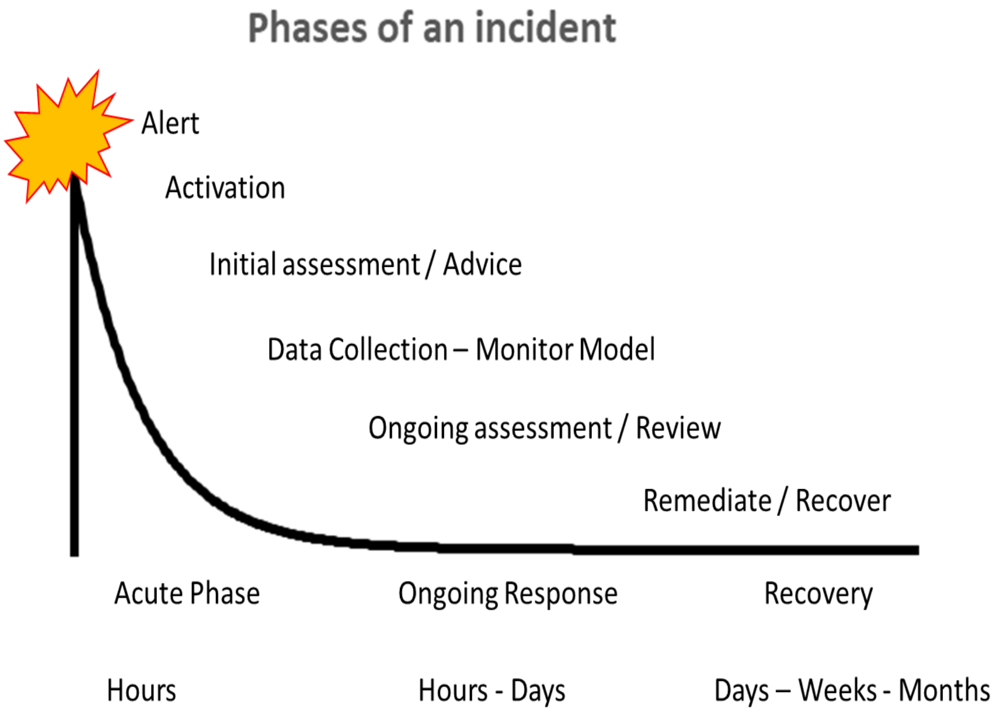


Figure 1: Phases of an Incident

2.1. Planning and Preparedness

Emergency planning is essential to prevent, reduce or mitigate the impact of incidents. Plans are generally tiered to cover national, regional and local scale incidents. A national plan is strategic, while regional and local plans will be more specific and recognise the key agencies involved in a response, likely hazards and risks, local receptors, operational logistics, resources and communication processes. Plans should be developed in line with local, regional or national emergency response protocols.

All principal parties, including the community, should be engaged in the planning and preparedness process. Regular training exercises should also be undertaken.

2.2. Initial Response

If airborne pollutants are released close to shore or in a port or harbour the immediate priorities should be to clear affected areas and to treat and remove casualties. Use of decontamination facilities and personal protective equipment (PPE) by specialist responders using their own operational procedures will form key elements of this phase.

In such circumstances it is often recommended to delineate the incident area into zones; The “Hot Zone”, nearest the incident where only responders have access, The “Warm Zone” for decontamination, and the “Cold Zone” where control and staging centres are located. The scale of such zoning will depend upon the incident (Figure 2).

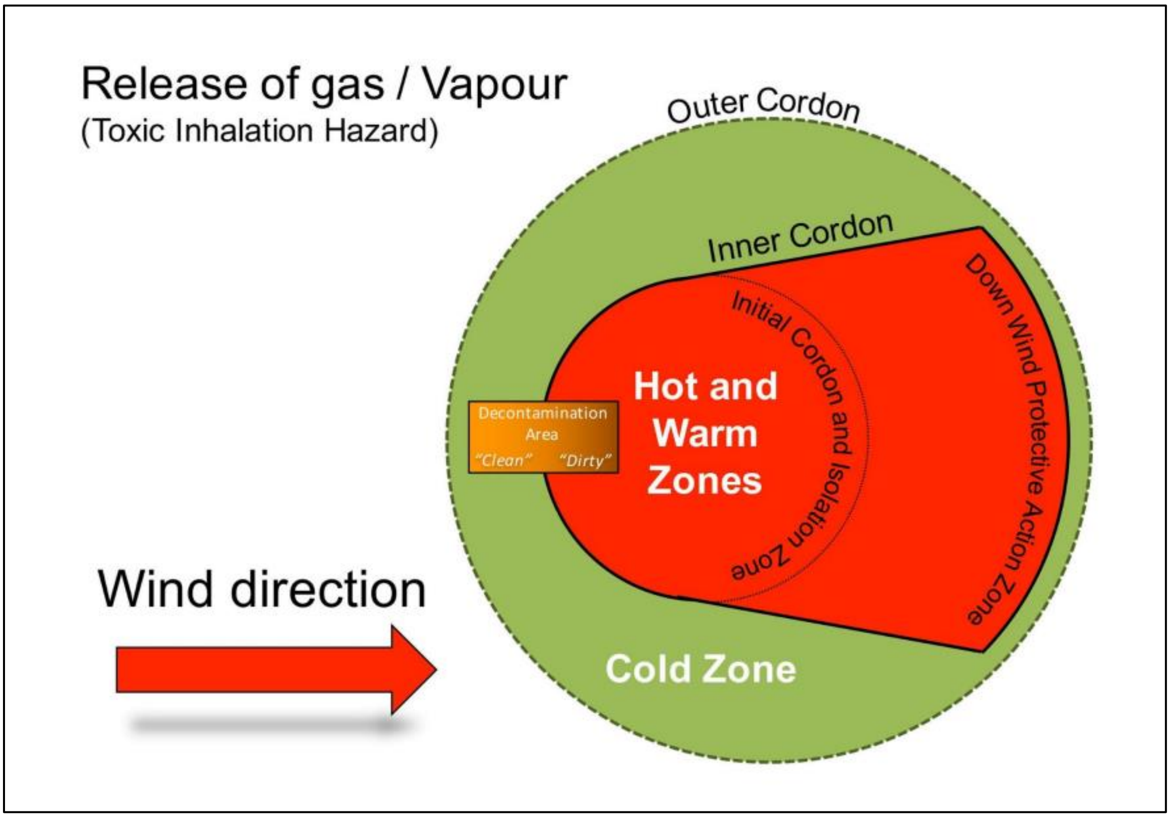


Figure 2: Illustration of Incident Zoning for Gas / Vapour Release[7]

[7] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiujJjO5qT2AhUXi1wKHSi0DVcQFnoECAUQAQ&url=https%3A%2F%2Fwww.ukfrs.com%2Fpdf%2Fdownload%2Fpromos%253A228243&usg=AOvVaw1Jdqgmu9A0LoZZ_T2OOLcC

Initial decisions on wider protective actions (beyond the zones defined above) will also need to be considered and will require risk assessment including collection of information about the incident as well as mobilisation of monitoring and modelling resources. These aspects are discussed in more detail in the following sections.

It is important to note that in the early stages of an incident, assessments and response need to be dynamic, evolving as more information is received. Communication, discussed further in section 6, is also an essential aspect of wider public protection.

3. RISK ASSESSMENT

As with all incidents the key to protection is based upon understanding what hazards are present and what is the likely risk of those hazards being encountered. A hazard can be defined as the intrinsic potential for a substance or activity to cause harm. Risk can be defined as the likelihood of that harm being realised.

Risk = severity of incident x likelihood of occurrence

Risk assessment is key to identifying the potential for exposure to the hazard and the potential impact of that exposure. Figure 3 below illustrates this process.

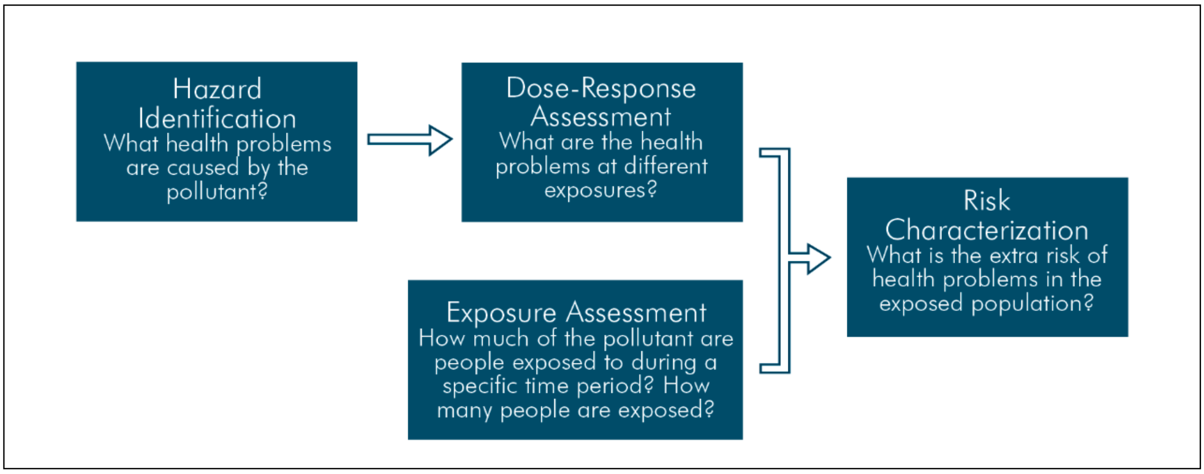


Figure 3: Illustration of risk assessment process (WHO)[8]

Risk assessment is typically applied using a source-pathway-receptor (S-P-R) approach. The source is the hazard and the receptor the entity that may be impacted

[8] WHO manual for the public health management of chemical incidents

such as a community, the environment or other sensitive infrastructure. For a risk to be present there must be a source, a receptor and a means of the two coming together (Pathway). Consequently, by removing one of these elements it is possible to mitigate the risk. Figure 4 below illustrates this for a gas or vapour release within a maritime setting.

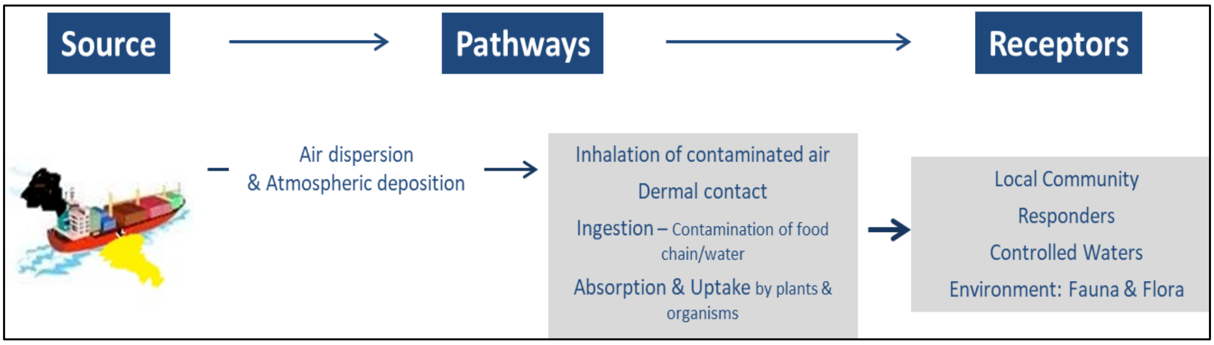


Figure 4: Illustration of Source-Pathway-Receptor Model[9]

4. PROTECTION OF WIDER COMMUNITIES

In terms of an incident involving an airborne release of a harmful chemical or chemicals the source will be present, until such time as it has moved away or been isolated. The release of a harmful substance does not mean that harm will occur. The key question is "is there a risk?". If there is no risk (of adverse health effects), and the public are not threatened, then no protective action is necessary. In practice this may be difficult to judge and precautionary protective action is advisable.

If taking no action is not an option, protection will involve either removing the receptor or breaking the pathway between source and receptor. For protection of the wider community this will typically equate to either evacuation (removal of receptor) or shelter (blocking the pathway by means of a physical barrier).

In both cases planning and preparedness is paramount as is the ability to communicate advice to the public, both during the incident and once the danger has passed. Pre-emptive engagement of communities in at risk areas is also advised.

[9] www.arcopol.eu

4.1. Evacuation

Removal of the population that may be affected by the airborne chemicals will ensure that no receptors are present and hence mitigate any risk, provided this is done quickly before outdoor conditions become too hazardous.

Evacuation may be advisable: when there is an immediate risk to people and properties (for example, from fire or explosion); when people can be evacuated prior to an exposure taking place; when the risk associated with sheltering will exceed the risk associated with evacuation (for example, for prolonged incidents)[10].

However, evacuation is not straight-forward, and a number of factors must be considered when making this decision. For instance will people be exposed to the chemical during evacuation, can all people be contacted and moved in time, will all people be willing to leave their homes, are there vulnerable populations who can't be moved or where moving might cause harm (hospitals, care homes), are facilities available to receive evacuees, is transport available? These factors need to be considered at planning stages to aid expedited decision making.

For maritime incidents, wider impacts from those occurring in ports or harbours are likely to affect urban or commercial areas. Vulnerable populations e.g. hospitals, care homes, schools, may be present in these areas. In coastal waters wider impacts on-shore may affect areas of dispersed populations and transient accommodation (holiday homes, camp sites etc.) adding difficulty to communicating messages rapidly and co-ordinating resources. All of these factors need to be considered.

Evacuation is often most appropriate for smaller discrete populations and also for non-residential settings such as commercial buildings, workplaces, educational facilities. Ideally, people should be evacuated away from, rather than through, areas affected by a hazardous plume; the feasibility of this depends on the specific scenario.

[10] Chemical Hazards and Poisons Report - Issue 27: September 2020 (publishing.service.gov.uk)

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The timing of evacuation is a key determinant and depends on the time taken to make the decision, to communicate this decision effectively and to organise resources. In many incident scenarios, there will be a limited time window during which evacuation can take place before people are exposed to an outdoor hazard (that is, before a plume arrives at their location). If evacuation cannot take place within this window, then evacuees may be exposed. The time of day that an incident occurs can greatly influence the feasibility of evacuation. During the night, complicating factors may introduce significant delays.

Exposure whilst evacuating may lead to debilitating health effects that hamper people's ability to evacuate. People at greatest risk from acutely toxic inhalation exposures include those with pre-existing cardio-respiratory disease and susceptible populations, such as children, pregnant women and the elderly.

Evacuation is almost always advised rather than imposed. Its effectiveness relies heavily on emergency planning and prior communication. Compulsory evacuation may impart feelings of a loss of control and an inability to protect family and friends.

Adverse effects on mental health after an evacuation can affect communities and place long-term demands on healthcare services.

4.2. Shelter in Place

Sheltering is an effective protective action that can be implemented rapidly to reduce population exposure. Requesting people to shelter indoors will provide a barrier to break or reduce the pathway for the chemicals to reach receptors. Sheltering advice will typically request the public to Go-in, Stay-in, Tune-in (to media sources).

The time taken by the public to respond is often cited in favour of shelter over evacuation. For the majority of chemical incidents and fires, an initial decision to issue shelter advice will be justifiable[10]. However, the effectiveness of sheltering must be considered on a case-by-case basis and be reviewed throughout the incident.

As a general rule, sheltering can be an effective mechanism for reducing exposure to peak concentrations over a limited time, but it may be less effective at reducing cumulative exposure over a longer time period as concentrations build up indoors. Studies have estimated the limit at which sheltering indoors might cease being effective, ranges from 30 minutes to a few hours, although sheltering for longer can be viable if outdoor exposures remain low and/or intermittent[10].

Typically, inhalation of a very high concentration for a short time is worse than inhalation of a lower concentration for a long time, even if the time-integrated dose is the same in both cases. As such cumulative exposure from lower concentrations can be less harmful than acute exposure to very high concentrations[10].

Standard advice for shelter in place includes:

- Keeping doors and windows closed, closing blinds and curtains if there is risk of explosion outside,
- Turning off air condition and ventilation systems or using recirculation mode,
- Sealing doors and windows with damp towels, if necessary, and even using showers to knock-out soluble gases.
- It is also very important to ventilate properties as soon as any danger has passed.

A number of factors influence the effectiveness of sheltering in place, relating to both the protection afforded by the shelter and the chemical specific health hazard posed by the release.

4.2.1 Air exchange

Air exchange is the most important factor determining the duration of protection e.g. at an air exchange of 1 change per hour, the indoor concentration reaches 50% of outdoor levels in about 2 hours. A rate of 0.5 increases this time to beyond 5 hours[11].

Air exchange is determined by ventilation and infiltration, which itself depends on factors such as a building's permeability, the wind speed, and the outdoor-indoor temperature differential. Ventilation such as chimneys can significantly increase air exchange.

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[11] Schmidtgoessling RD. SHELTER-IN-PLACE: INDOOR EXPOSURE ASSESSMENT DURING AN AIRBORNE CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR (CBRN) EVENT. Air University, 2009

4.2.2 Building characteristics

Building size and type are also important with larger buildings having larger reservoirs of air thus increasing dilution. As a rule of thumb apartment blocks and large multistorey buildings offer the best protection. And it is generally viewed that most protection will be in an upper floor room on the opposite side of the building from the wind (Leeward side)[10].

Building age is also important as older properties may be less airtight than newer builds which comply to modern energy efficiency rules.

Buildings can also react with chemicals immobilising them and reducing ingress. Fixtures and furnishings can do this, although conversely immobilised chemicals can subsequently be released over time posing potential residual risks.

4.2.3 Toxicity

For many chemicals, the exposure concentration will eventually determine the effect, and this is not simply a combination of concentration and exposure time. The "toxic-load exponent" or "n value" is a chemical-specific parameter that characterises the dose-response relationship[12]. It can be used to calculate "toxic load" (TL), a metric that recognises that chemicals elicit different responses over different concentrations and timescales. For any given chemical, when the load exceeds a certain limit, adverse health effects are likely to occur. This is called the "toxic load limit" (TLL), and the concept is fundamental to the derivation of many guideline levels for acute exposure during emergencies. Thus, comparison of concentrations with appropriate chemical specific acute health guidelines is important in evaluating potential risks.

[12] Chan WR, Nazaroff WW, Price PN, et al. Effectiveness of urban shelter-in-place-I: Idealized conditions. *Atmos Environ* 2007;41(23):4962-76.

5. DECISION MAKING PROCESS

There has been much work undertaken on the merits of sheltering versus evacuation and decisions need to be made on an incident specific basis[10,13]. While sheltering can be implemented rapidly, in some circumstances evacuation may be advisable, such as: when there is an immediate risk to surrounding properties (for example, from fire or explosion); when people can be evacuated prior to an exposure taking place (for example, before a release has occurred or before it has moved to their location); when an incident is likely to be prolonged (for example, when the risk associated with sheltering exceeds the risk associated with evacuation, though this is difficult to predict).

5.1. Considerations for Initial Assessment

In reality, balancing the chemical risks associated with exposure (indoors or outdoors) and non-chemical risks associated with evacuation is difficult and can rarely be done in a timely or satisfactorily quantitative way during an incident.

To inform decisions however, a number of initial questions should be asked about the incident and its potential impacts, including:

- Chemical(s) involved, their hazards, behaviour and quantity released and likely duration. (Source)
- Prevailing Weather conditions – wind speed and direction. Topography (Pathway)
- Distance to receptors, building types, environment (rural or urban). (Receptor)

Knowledge of the type of chemicals involved will enable decisions to be made on what hazards are posed. Information on chemicals involved can be obtained directly from identification labels or obtained from the port or ship operators. Potential hazards can then be identified via safety data sheets or on-line databases[14],[15].

[13] Gaseous releases from maritime incidents — REMPEC Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC)
[14] https://www.hns-ms.eu/hnsdb
[15] CAMEO Chemicals | NOAA

Reference to health-based standards can indicate the type and severity of hazards posed by exposure to a chemical. In the case of incident response, it is advisable to use acute exposure standards such as protective action criteria[16] (PAC) which provide an airborne concentration established to be protective of the public for a defined exposure period based upon either toxicity or flammability / explosion. Literature review identified several HNS commonly associated with maritime incidents including Ammonia, Chlorine, Hydrogen Sulphide, Liquified Petroleum Gas (LPG), and volatile hydrocarbons. A list of PACs relevant for these HNS is provided in Appendix 2.

An estimate of release size will help to indicate potential risk. The scale of an incident can also indicate whether the release will be short-lived or prolonged over several hours. The emergency response guidebook (ERG) estimates spill sizes as small being a drum or cylinder or large, a road / iso tank (about 50m^3). As stated previously, ships tanks can contain as much as 10,000 m^3 as can shore tanks.

A small release is likely to result in all of the chemical becoming airborne quickly, while a large release or slow escape is likely to result in an ongoing gas or vapour cloud over several hours. As a general rule a rapid release will result in higher outdoor concentrations more quickly thus reducing the time for evacuation. In contrast, longer releases will result in potential for cumulative exposure over a longer period which may make sheltering a less favourable option.

Whether a gas or vapour is lighter or heavier than air will also be important in how it travels on release. In general terms heavier gases and vapours will travel shorter distances than lighter buoyant clouds. However heavier than air clouds will remain close to the ground and pose a higher risk of exposure to those in its path.

Literature review suggests dense gas clouds represent the most common type of release. Buoyant gases are far less common with methane (liquified natural gas or LNG) being the most notable carried by sea. However typically during an incident LNG will also behave like a dense gas on release to atmosphere due to its low

[16] https://www.epa.gov/aegl/access-acute-exposure-guideline-levels-aegls-values#chemicals
https://edms.energy.gov/pac/Search

temperature when transported. Fires can increase buoyancy of gases and vapours due to the high temperatures at the release source, with clouds subsequently grounding beyond their point of origin as they cool and become denser.

Pathways

The key pathway following release of a gas or vapour will be its airborne transport. Thus, knowing the prevailing wind speed and direction will be important in determining the receptors at highest risk of exposure. These data can generally be obtained via national metrological services, on-line weather sites or weather apps on smartphones. In guidance such as The Emergency Response Guidebook[2] wind speed is estimated as light (less than 10 km/h), moderate (between 10 to 20 km/h) and strong (greater than 20 km/h.)

Topography can also be an important factor particularly for dense gases and vapours. Ports and shorelines are often low lying with cliffs or steep slopes separating them from the wider community. Such topography can potentially slow the movement of the gas or vapour to inland areas. This may allow more time when considering evacuation but requires judgement to be made on a site-specific basis.

Receptors

The key information will be the presence of and distance to any community downwind of the source. In addition, the size of the population, the presence of vulnerable populations such as hospitals and transport infrastructure will be important with regard to potential for evacuation, while the nature of the environment and type of buildings occupied will be useful in terms of assessing sheltering in place. Much of this information can be obtained from maps, site response plans and observations.

Where incidents occur in ports it is likely that surrounding communities will be urban or commercial represented by permanent buildings affording a degree of protection for sheltering. Populations are also likely to be large with potential for vulnerable groups which may restrict options for rapid evacuation.

In contrast for incidents in coastal waters the nearest onshore communities may comprise less-permanent structures such as cabins, caravans and camp sites.

These would afford limited if any protection for sheltering. However, populations are likely to be small and possibly more conducive to rapid evacuation.

5.2. Decision Process

While different approaches have been advocated, no single approach to decision-making for chemical incidents has achieved widespread acceptance based on validity, utility and effectiveness[10].

Short-term exposure to high outdoor concentrations (such as may be experienced when evacuating) is more likely to lead to acute health effects than a longer-term exposure to lower indoor concentrations. The significance of exposure, and its implications for evacuation, will depend on the toxicological properties of a given substance and must be considered on a case-by-case.

In instantaneous chemical release scenarios, there is a predisposition towards shelter. For prolonged releases over longer durations, sheltering may become less effective.

It is not possible to specify in advance an exact period beyond which sheltering will become ineffective, but studies used and applied in emergency planning[17] suggest a plume duration (that is, hazardous levels outdoors) of less than 30 minutes being more 'towards' sheltering and over 120 minutes more 'towards' evacuation. Australian guidance[18] for fires considers sheltering appropriate for incidents of 1 hour or less and prompts consideration of evacuation for releases lasting over 4 hours.

In intermittent release and exposure scenarios it may be possible for people to shelter downwind for longer periods of time, with options to ventilate rooms when plumes are not present.

The use of modelling can predict indoor exposures and support shelter and evacuation decisions. Given predictions of outdoor concentrations, the additional information required to model indoor concentration is, in essence, the air exchange rate and predicted loss due to attenuation. A number of relevant software models

[17] Sorensen JH, Shumpert BL, Vogt BM. Planning for protective action decision making: Evacuate or shelter-in-place. J Hazard Mater 2004;109(1-3):1-11

[18] Metropolitan Fire and Emergency Services Board (MFB) [Australia]. A Best Practice Approach to Shelter-in-Place for Victoria. 2011.

exist, of varying levels of complexity[19,20]. Detailed modelling is best undertaken as part of emergency planning and preparedness rather than during response as such modelling can be time consuming and may not be suitable in a response situation where there may be time pressures.

An example of such modelling is presented below (Figure 5) to demonstrate the impact of different parameters on building ingress and the protective effects of sheltering.

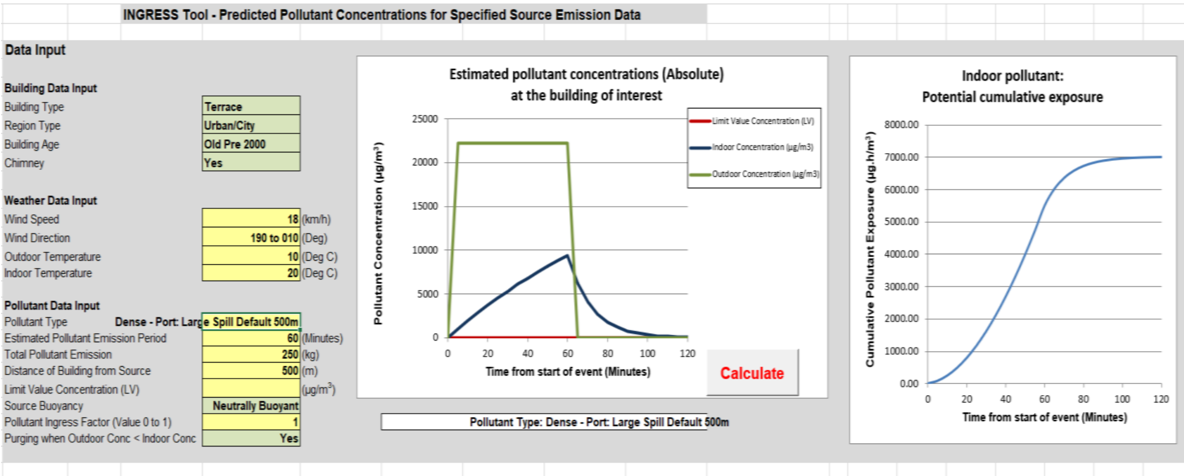


Figure 5 Illustration of Building Ingress Model Output

Comparing modelled maximum indoor and outdoor concentrations (exposure) with relevant standards (PACs) for the chemical or chemicals involved in the incident can provide an initial indication of potential exposure.

For example, consider a spill from an ISO tank at a port with residential areas 500m downwind. The estimated modelled maximum concentrations at the receptor for a dense (heavier than air) chemical and the described spill scenario are presented below.

Spill Size	Receptor Distance m	Wind Speed	Maximum Outdoor mg/m³	Maximum Indoor mg/m³	Cumulative hourly Indoor exposure mgh/m³
Large (60-minute release)	500 Urban	Moderate Default	**22**	**10**	**7**

[19] https://www.nist.gov/el/energy-and-environment-division-73200/nist-multizone-modeling/software-tools/contam

[20] Montoya MI, Planas E, Casal J. A comparative analysis of mathematical models for relating indoor and outdoor toxic gas concentrations in accidental releases. *Journal of Loss Prevention in the Process Industries* 2009;22(4):381-91.

If the spill was ammonia then the health-based protective action criteria (PAC) are 21 mg/m^3 (transient effects) and 77 mg/m^3 (potential permanent effects) for up to 8 hours exposure.

Comparing the modelled maximum concentrations to the standards for ammonia, it is clear that indoor concentrations are well below those that could cause harm while the maximum outdoor standard is slightly in excess of PAC 1 (transient effects). Thus, shelter indoors should be suitable as the immediate protective action.

If the release however had been chlorine, then the PACs would be between 1.5 to 5.8 mg/m^3 which are below both indoor and outdoor estimated concentrations. As such sheltering is unlikely to afford complete protection and prompt evacuation may be the best option if possible.

Maximum Outdoor mg/m^3	Maximum Indoor mg/m^3	Ammonia PAC 1 mg/m^3	Ammonia PAC 2 mg/m^3	Chlorine PAC 1 mg/m^3	Chlorine PAC 2 mg/m^3
22	10	21	77	1.5	5.8

In addition to maximum concentrations, modelling may also present cumulative hourly exposure reflecting the dose received by those sheltering. Dose is a function of exposure concentration and duration. As indoor concentrations tend towards outdoor concentrations over time, the indoor dose will tend towards the outdoor dose in the longer-term increasing the cumulative dose.

As a general rule, sheltering can be an effective mechanism for reducing exposure to peak concentrations over a limited time, but it may be less effective at reducing cumulative exposure over a longer time period as the concentrations build up indoors[10].

This also highlights the need to ventilate properties as soon as the danger has passed.

Pre-prepared information and guidance can reduce the time required by emergency responders in the response phase of an incident to collect and assess information, make a decision about sheltering and evacuation, and communicate and implement it. With this in mind UKHSA have developed an algorithm (Appendix 1) combining a flow chart of steps to be taken during the initial phases of the incident combined with a procedure outlining information needed to inform decision making whilst considering key limitations for each option. The field guide provides further tools to complete the process.

5.1. Ongoing Response - Obtaining Further information

The principle consideration for maritime incidents involving airborne releases is the rapid rate at which pollutants can travel beyond the source. This means that decisions often have to be made before detailed monitoring or modelling data are available.

In some cases, environmental monitoring may be available on-site or with emergency responders while fixed regulatory air quality monitors may provide real time data on shore. Some rapid dispersion models such as the UK Met office CHEMET service[21], or models such as USEPA ALOHA[22] and EU MANIFESTS models[1] can give quick results to help to inform the process.

It is important to review the risk assessment as more data are collected and if necessary, revise advice.

5.2. Recovery Phase

Incidents may result in acute and chronic effects both physical and psychological. After the acute (incident) phase the event will enter the Recovery phase. This represents the longer-term response once immediate risks have been managed and incident command and control structures established.

Recovery may initially continue to address immediate issues of the release developing the risk assessment as more data are received. Beyond this recovery will look at the long-term restoration to normality[23]. Some key elements for consideration during recovery may include assessment and management of risks from deposited

[21] Chemical Meteorology (CHEMET) service - Met Office

[22] USEPA ALOHA ALOHA Software | US EPA

[23] UK recovery handbook for chemical incidents (publishing.service.gov.uk)

materials e.g. dissolved chemicals washed out by weather or water curtains, or ash deposited from fires or explosions, both of which may potentially affect foodstuffs, water supplies and local environments.

Recovery will also require follow up of those communities involved in the incident and will incorporate economic, environmental and health aspects (both physical and psychological).

6. COMMUNICATION, ADVICE AND ENGAGEMENT

Having a mechanism in place to facilitate effective communication is essential. Incident communication will fall into 2 categories[24]:

Risk communication – Developed at the planning stage and involving preparation of predetermined materials regarding hazards and response. This should be done in liaison with all stakeholders including local communities. Stakeholder engagement is an important stage of this to engage communities and include their views.

Crisis Communication – Applied during an incident and involving essential advice (Warning and informing) such as sheltering, evacuation, all-clear messages etc. via various media. Platforms such as social media and the internet will form significant mechanisms for these activities in addition to conventional methods such as mail drops, public meetings and formal press statements.

Key points for Communication

- Prompt warning and informing is critical as delays have the potential to significantly reduce the effectiveness of sheltering and evacuation strategies.
- Communication must continue throughout an incident and include messages about when to end sheltering or evacuation.
- Following an incident, as many civil alerting systems as possible should be used. No one system is a "silver bullet" that can reach the entire "at risk" population. The use of different systems helps to reinforce shelter and evacuation messages

[24] Arcopol / Training & Awareness

- A wide range of traditional alerting mechanisms such as route alerting (door-knocking and loudhailers) sirens, mass media and phone information lines may be used to communicate with the public following an incident.
    - The additional contribution made by informal networks (for example, family, friends and social media) is significant in propagating messages
    - The internet (for example, via social media) can be a valuable tool for communicating with the public during an incident. Be mindful however that in coastal / rural areas this option may be limited. If possible, monitor social media "chat" to gauge the impact of advice and gain information "on the ground"[25]
- People generally do not panic during an incident, but there are numerous psychosocial factors that influence whether people comply with emergency responders' advice. Messages must be clear and barriers to communication must be addressed
- Different groups of people often trust different sources, and people will try to validate messages. Therefore, consistent messages should ideally be repeated by as many different authoritative sources as possible, ensuring messages are consistent.

In addition to the above, it is also important to review and communicate operational performance in the form of regular strategic, tactical, and operational meetings during an incident and also from post incident debriefs.

This will identify any potential issues during the response and highlight lessons learnt, aiding continuous improvement. It also provides a means of ensuring decisions are recorded for later scrutiny and investigation.

[25] EU Hazrunoff Project

7. CONCLUSIONS

Release of airborne pollutants can quickly migrate beyond the scene of the incident with the potential to impact wider communities. Planning and preparedness are important to enable a prompt response and issue timely advice to the public.

Maritime incidents in coastal waters (and even in ports) can offer a range of challenges such as; potential chemicals involved, scale of incident, accessibility and location specific factors such as population / conurbation type, infrastructure, communication.

In the absence of detailed assessments, it will be necessary to provide a best estimate of risks to promptly inform possible protective action options. To complete this it is important to collect some basic data about the incident, namely; the chemicals involved and their hazards, the size of release (small, large, very large), prevailing weather (wind speed and direction), and the nearest populations.

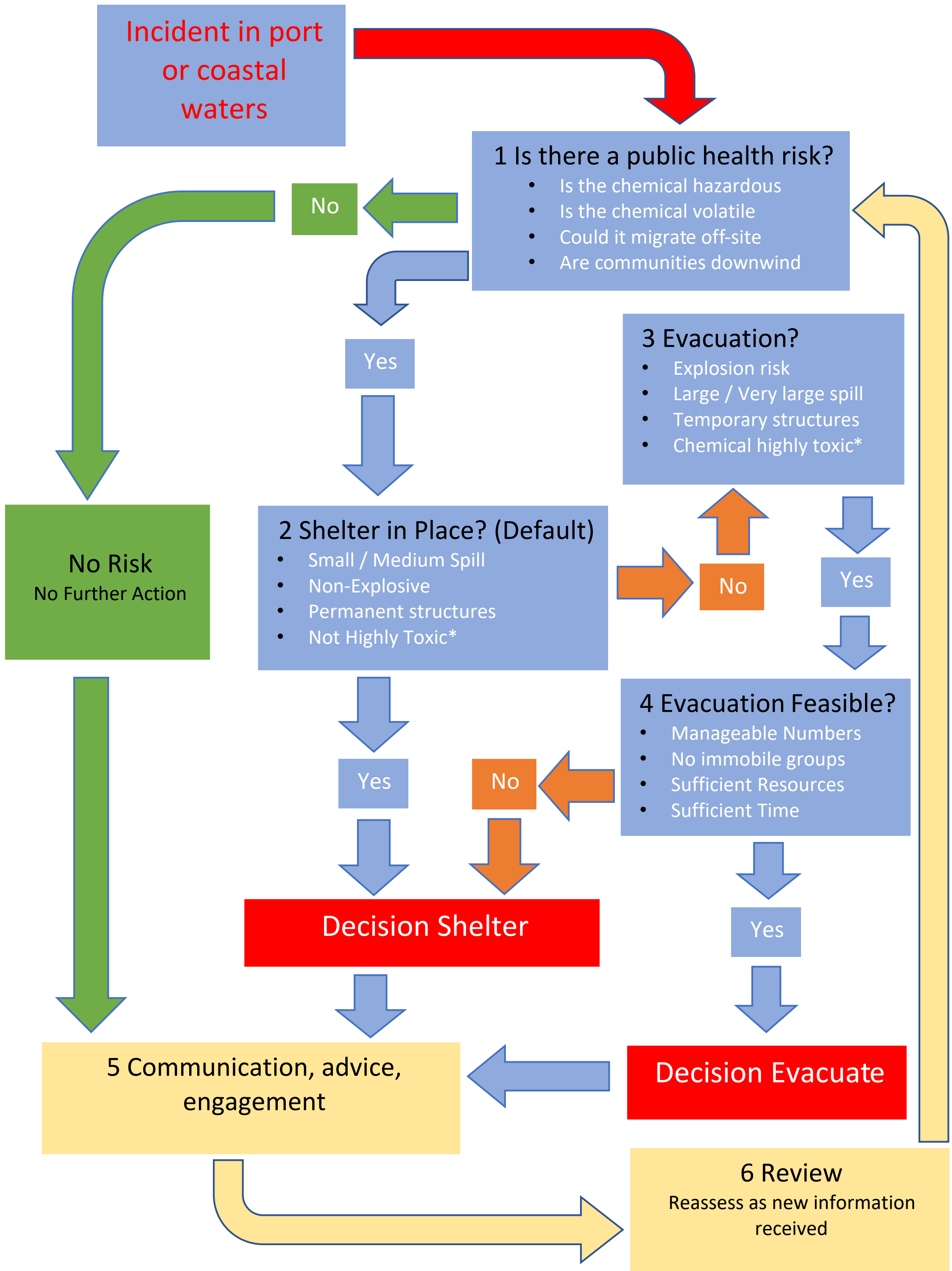
Using this information, a series of initial actions should be considered including

- Evacuation of the immediate area (hot zone) using responder protocols and / or guidance such as the Emergency Response Guidebook for zoning distances. This approach should also be used where there is a serious risk of explosion.
- Apply initial incident information to inform wider protective actions and assess shelter versus evacuation options (Appendix 1), noting limitations of each.
- Issue prompt clear advice via media and social media and by means of physical attendance, if necessary and safe to do so.
- Review advice as more detailed monitoring and modelling data are received
- Update messages as the incident develops.
- Where sheltering advice has been provided, inform the public to ventilate properties as soon as the risk has passed.

Alongside this it is also important to initiate mitigation measures to terminate the release and / or reduce plume movement as early as possible using appropriate response techniques[26]

[26] www.westmopoco.rempec.org

APPENDIX 1: Decision Algorithm[27]



* Highly Toxic - PAC2 less than 2 ppm (Appendix 2) / Seek specialist chemical advice

[27] Factors listed in each box are considerations to aid decision process and should be reviewed in context of site conditions. Final decisions will require an element of judgement by the responder.

Algorithm Guidelines

If there is a potential risk to a wider community? (<1.5 km downwind[28])

Default advice should be **Shelter in Place –** Stay indoors preferably in a room away from the wind and on an upper floor. Close all doors and windows and turn off air conditioning / ventilation systems. If instructed place damp towels cloths around doors and windows. Monitor media / social media for updates.

Challenges to default advice

Is there a risk of explosion affecting the community?

Is the release likely to be prolonged i.e., more than 2 hours? (large / very large ongoing release of gas, or large / very large spill of evaporating substance. In contrast, an instantaneous large / very large release of gas or vapour may result in a rapidly formed major cloud moving off site and may make evacuation unsafe)

Are there communities in temporary structures (tents, caravans, cabins)?

Is the chemical considered highly toxic (Seek expert chemical advice - Appendix 1)?

If yes to any of the above

Evacuate where feasible i.e., can be achieved before outdoor concentrations become hazardous (2 hours[29]), have sufficient resources / infrastructure to manage evacuation, provide rest centres and if necessary, offer decontamination facilities.

Further Considerations

If not feasible where susceptible / immobile populations are present and cannot be evacuated easily or where this may pose unacceptable risk to health from acute exposure, revert to default shelter advice for this group.

Communicate Advice promptly – using all available channels

Review

Review decisions upon receipt of any new information from scene, or from monitoring / modelling. Update Messages after each review. Where and when appropriate inform communities to ventilate buildings

Provide ongoing advice regards longer term concerns (residual deposition on surfaces, crops / foodstuff, sorbed chemicals on fabrics / furnishings**) and on support available (**medical, well-being, economic, social**)**

[28] 1.5 km is indicative and should be reviewed as site information develops or in line with local emergency plans
[29] 2 hours is indicative and can be reviewed in line with local emergency plans

APPENDIX 2: Representative Protective Action Criteria

Chemical Name	PAC Level	1 hour mg/m³	8 hour mg/m³	Odour mg/m³	Conversion from mg/m³ to ppm
Ammonia	PAC-1	21.0	21.0	4.0	X 1.4
	PAC-2	77.0	77.0		
Chlorine	PAC-1	1.5	1.5	1.5	X 0.35
	PAC-2	5.8	2.0		
Hydrogen Sulphide	PAC-1	0.70	0.46	0.014	X 0.7
	PAC-2	39.0	24.0		
Hydrogen chloride	PAC-1	2.7	2.7	0.1 to 1.4	X 0.7
	PAC-2	33.0	17.0		
Hydrogen Fluoride	PAC-1	0.8	0.8	0.017	X 1.2
	PAC-2	20.0	10.0		
Benzene (BTEX)	PAC-1	170.0	29.0	4.9	X 0.3
Methane (LNG) Flammability	PAC-1	43000.0	-	NA	X 1.5
	PAC-2	150000.0	-		
Butane (LPG)	PAC-1	13000.0	13000.0	3.0	X 0.4
	PAC-2	40000.0	40000.0		
Ethylene Oxide	PAC-1	NA	NA	470.0	X 0.5
	PAC-2	81.0	14.0		
Kerosene (Jet Fuel JP5 and 8)	PAC-1	290.0	290.0	0.6	X 0.12
	PAC-2	1100.0	1100.0		
Gasoline (as Octane)	PAC-1	2900.0	-	2900.0	X 0.2
	PAC-2	12000.0	-		
Formaldehyde	PAC-1	1.1	1.1	4.5	X 0.8
	PAC-2	17.0	17.0		
Nitrogen Dioxide	PAC-1	0.9	0.9	0.8	X 0.5
	PAC-2	23.0	13.0		
Carbon monoxide	PAC-1	NA		NA	X 0.9
	PAC-2	95.0	31.0	NA	
Sulphur Dioxide	PAC-1	0.5	0.5	1.8	X 0.4
	PAC-2	2.0	2.0		

PAC 1 is concentration above which transient effects may occur. PAC 2 represents a concentration above which more permanent effects on health may occur at the relevant exposure duration.

APPENDIX 3: Illustrative Case Studies

The following case studies have been included to illustrate use of the field guidance / algorithm in aiding decision making during different incident scenarios within a desk top training/exercise situation.

It should be emphasised that the guidance is never likely to offer a perfect fit to an incident scenario. As such there will always need to be a degree of judgement by responders.

The guidance aims to signpost the user through logical, rapid steps to reach a best initial option and is intended to be primarily applied in training and planning activities to help responders develop understanding and appreciation of fundamental considerations when decision making.

Refer to the field guide document when reviewing the case studies to see how the various text, links and data collection aids can be applied to a scenario.

Case Study 1

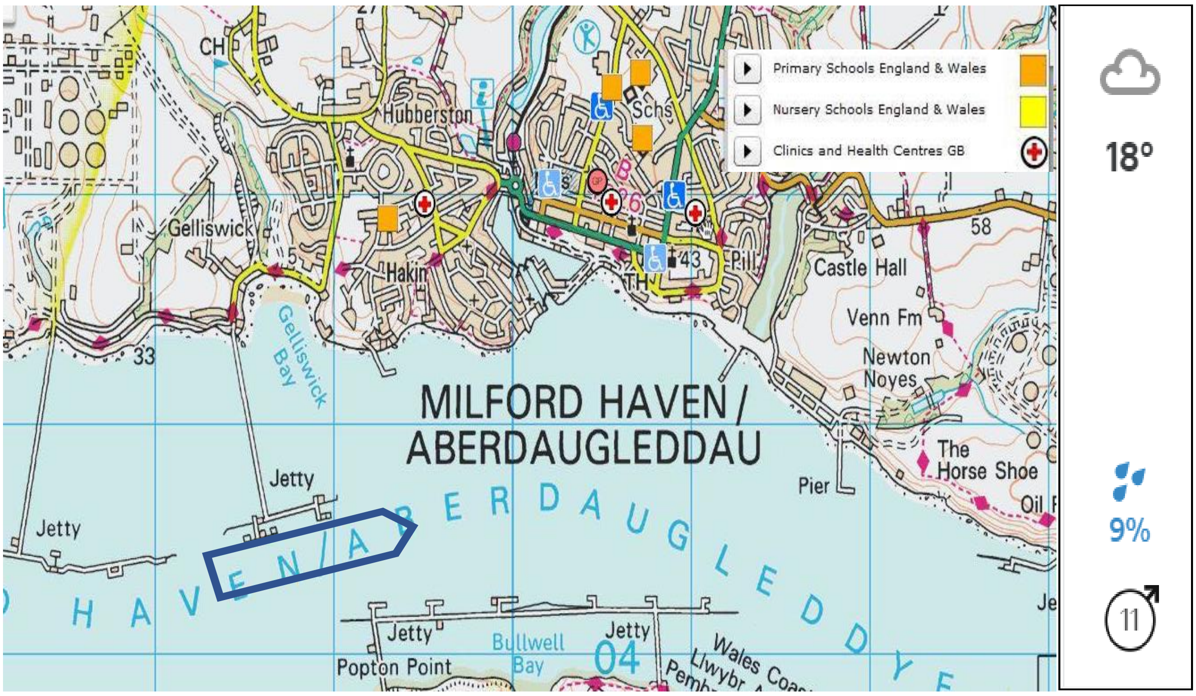
MV ‘Dark Cloud’ a fully laden 4,000 Gross tonne LNG tanker is currently in distress in the Celtic Deep. Captain has reported engine failure. The ship is drifting. Position 2 km off-shore SW Milford Haven. Requested towing to place of refuge. Agreed with Port Authority to use emergency jetty in Pembroke Haven.

Is there a potential risk to the port and wider areas?

Use the guidance to identify potential risks by collecting available information on source-pathway-receptors (chemical, weather, local receptors) using data collation sheet. Chemical is Liquified Natural Gas (Methane). On-line weather and maps below.

Is there a public health risk?

- Is the chemical hazardous
- Is the chemical volatile
- Could it migrate off-site
- Are communities downwind



Is there a public health risk? – Yes

- Is the chemical hazardous – Methane - Flammable/explosive / low toxicity PAC>2
- Is the chemical volatile – yes buoyant gas
- Could it migrate off-site – yes potential large release. Wind to NE
- Are communities downwind – yes – town of milford downwind

What Decisions need to be agreed regards the safety of immediate area / wider communities?

Default advice is Shelter in Place – Stay indoors. Close all doors and windows and turn off air conditioning / ventilation systems. Monitor media / social media for updates.

Challenges to default advice? - See challenges in field guide

Evacuation?

- Explosion risk? – **Gas is explosive at 5 to 15%** - Unlikely beyond port
- Chemical highly toxic* - No PAC >2ppm
- Large / Very large spill – Possible – large volume of gas venting – **may be >2hours**
- Temporary structures – No – adequate protection for sheltering

Is Evacuation Feasible? - See field guide

Evacuation Feasible?

- Manageable Numbers? – Whole Town - unlikely
- No immobile groups - potential immobile groups (medical facilities)
- Sufficient Resources? - Whole Town - unlikely
- Sufficient Time? – Whole Town - unlikely
- Acceptable Exposure? – Gas likely to reach town before evacuation possible

Answer – Wider evacuation not likely to be feasible.

Decision

Shelter in place for wider community - based upon large population to evacuate, the likely presence of immobile groups (medical facilities), the relative low toxicity risk and the buoyancy / dispersion of the gas beyond the site limiting explosive risks. The immediate port area should be evacuated using operator emergency plans due to explosion risk. An exclusion zone should be established for the vessel and all traffic stopped from entering / leaving the Haven.

Case Study 2

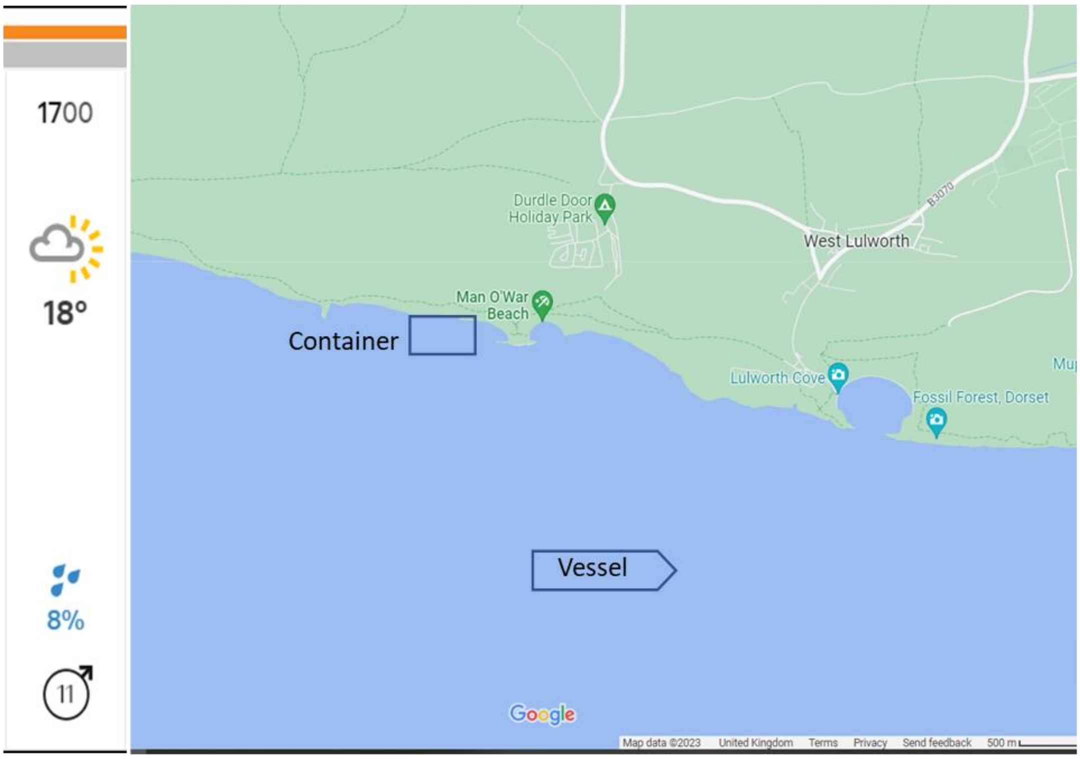
17:00 hrs - MV ‘Happy Sunrise’ a fully laden 20,000 Gross tonne container ship has run aground off the coast of Dorset. Position 1 km off-shore SW Lulworth. Captain has reported a number of containers have been lost overboard and are drifting onto rocks due to tide and onshore wind. One container is carrying several tonnes of Sodium Chlorate (CAS No 7775-09-9), which can produce chlorine gas on contact with water. Responders are at the scene and have reported containers breaking on rocks and contents becoming exposed to sea water.

Is there a potential risk to the port and wider areas?

Use the guidance to identify potential risks by collecting available information on source -pathway-receptors (chemical, weather, local receptors) using data collation sheet. Chemical of concern is Chlorine gas. On-line weather and maps below

Is there a public health risk?

- Is the chemical hazardous
- Is the chemical volatile
- Could it migrate off-site
- Are communities downwind



Is there a public health risk? - Yes

- Is the chemical hazardous – Chlorine – Highly Toxic
- Is the chemical volatile – yes dense gas (will stay close to ground level)
- Could it migrate off-site – yes potential medium / large release.
- Are communities downwind – yes – holiday camp downwind. Tourist beach.

What Decisions need to be agreed regards the safety of immediate area / wider communities?

Default advice is Shelter in Place – Stay indoors. Close all doors and windows and turn off air conditioning / ventilation systems. Monitor media / social media for updates.

Challenges to default advice? - See challenges in field guide

Evacuation?

- Explosion risk? – **No**
- Chemical highly toxic* - **Yes** PAC <2ppm
- Large / Very large spill – No potential medium / large but gas generation **may be prolonged >2hours**
- Temporary structures – **Yes** – inadequate protection for sheltering

Answer – Yes

Is Evacuation Feasible? - See field guide

Evacuation Feasible?

- Manageable Numbers? – **Yes**
- No immobile groups - **None**
- Sufficient Resources? - **Yes**
- Sufficient Time? – **Possible**. Need to initiate immediately
- Acceptable Exposure? – **Probable** if initiated before gas generated (Paramedics and decontamination facilities should be readied for receipt of residents)

Answer – Yes – Immediate action required

Communication, advice, engagement

- Possible limited receipt of media / social media messages
- Will need to attend site and beaches
- Will need to close access to site and local area
- Issue shelter to properties further downwind as precaution
- Will need clear messages for return once incident over

Review

- Will need to update assessment on receipt of any new developments
- Will need to ensure site / properties safe before re entry
- Should initiate health register for follow up post event

Conclusion

The immediate action for the holiday park community is evacuation due to proximity to toxic risk and nature of properties. Shelter in place is advisable for wider community based upon low lying nature of dense gas limiting extensive migration and dilution dispersion over longer distances.

Using local emergency plans issue communications and attend holiday park. Ready medical and decontamination support for residents that may be briefly exposed during evacuation. Close roads and beaches to public.

Once incident phase is over, ensure holiday homes, and other structures, as well as low lying areas, voids, drains etc., are given all clear by response services before allowing residents to return. Advise those sheltering to ventilate their properties as a precaution. Consider initiating a health / follow-up register for those evacuated.