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Emergency planning and the Control of Major Accident Hazards (COMAH/Seveso II) Directive: An approach to determine the public safety zone for toxic cloud releases

Mary T. O'Mahony [a,*], Donal Doolan [b], Alice O'Sullivan [c], Michael Hession [b]

[a] *Department of Public Health, Health Services Executive – Southern Area, Sarsfield House, Sarsfield Road, Wilton, Cork, Ireland*
[b] *Cork County Fire and Rescue Service, North Mall, Cork, Ireland*
[c] *Cork Joint Emergency Planning Office, Health Services Executive – Southern Area, Unit 5 South Ring Business Park, Kinsale Road, Wilton, Cork, Ireland*

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Abstract

The EU Control of Major Accidents Hazards Directive (Seveso II) requires an external emergency plan for each top tier site. This paper sets out a method to build the protection of public health into emergency planning for Seveso sites in the EU. The method involves the review of Seveso site details prescribed under the directive. The site safety report sets out the potential accident scenarios. The safety report's worst-case scenario, and chemical involved, is used as the basis for the external emergency plan. A decision was needed on the appropriate threshold value to use as the level of concern to protect public health. The definitions of the regulatory standards (air quality standards and occupational standards) in use were studied, how they are derived and for what purpose. The 10 min acute exposure guideline level (AEGL) for a chemical is recommended as the threshold value to inform decisions taken to protect public health from toxic cloud releases. The area delimited by AEGL 1 defines the population who may be concerned about being exposed. They need information based on comprehensive risk assessment. The area delimited by AEGL 2 defines the population for long-term surveillance when indicated and may include first responders. The area delimited by AEGL 3 defines the population who may present acutely to the medical services. It ensures that the emergency responders site themselves safely. A standard methodology facilitates discussions with plant operators and concerned public. Examples show how the methodology can be adapted to suit explosive risk and response to fire.

Keywords: Seveso directive; Emergency planning; Major hazards; AEGL; Exposure limit

1. Introduction

The paper sets out a method to determine the limits of a public safety zone in emergency plans for chemical accidents. An uncontrolled release of dioxin from a chemical plant near the town of Seveso in Italy in 1976 resulted in health effects in exposed local population. This accident gave its name to the European Union directives, the Seveso I [1] and Seveso II [2] directives, brought in to control major accident hazards. Under the Seveso II directive emergency planning is required for sites, the top tier sites that store or could generate quantities of dangerous substance in excess of specified thresholds. This is usually done jointly by the emergency response agencies. Regular review and testing of the plans at least every 3 years is required with public participation and consultation. The directive requires establishments to provide the local competent authorities with information to enable them to draw up off-site plans. Each member state designates a competent authority to enforce the directive.

The overall approach to the management of a "Seveso" emergency is the same as any other emergency. The principles established in the all hazards regional major emergency plan would be applied. The same applies to the incident site in terms of establishing a layout along planned lines to facilitate control and security. An external emergency plan should be read and

* Corresponding author. Tel.: +353 21 4927601; fax: +353 21 4346063.
E-mail addresses: maryt.omahony@mailp.hse.ie (M.T. O'Mahony), donal.doolan@corkcoco.ie (D. Doolan), aosullivan@nicholasodwyer.com (A. O'Sullivan), michael.hession@corkcoco.ie (M. Hession).

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implemented in conjunction with the company's on-site emergency response plan for the establishment. The external emergency plan is a site-specific appendix of the regional major emergency plan.

Using site-specific information on the nature of the risk involved, the external emergency plan for each Seveso site should prepare the first responders to protect themselves in the emergency response situation. The external emergency plan should also inform first responder decisions and actions to protect the population working or living proximal to the site and the potentially exposed population. The input of the public health authority is required.

In the Irish Health Services Executive – Southern Area (counties Cork and Kerry) the local competent authorities (fire, ambulance and police) have a jointly produced generic major emergency plan. This plan covers a population of 620,525 [3] and an area that includes 14 top tier and 12 lower tier Seveso II sites [4]. A jointly funded emergency planning officer assists generally with major emergency planning and draws up the external emergency plans for the Seveso sites in the area. In approaching the task locally the public health authority was asked to identify and confirm the threshold values to use to delimit the public safety zone in the Seveso site external emergency plans. The public health authority devised the methodology in conjunction with the assistant chief fire officer and the emergency management officer. This involved a definition of the public safety area. A review of published exposure levels was done to identify the best fit for the protection of public health.

This paper sets out an interagency approach to setting the emergency planning distance when there is a toxic cloud involved, incorporating public health parameters. It shows how the methodology can be adapted to other types of major emergencies. A standard EU approach is recommended.

2. Review of the literature

2.1. Major emergency plans for chemical incident response need a public health approach

Major emergency plans are written in general terms to cover all common hazards and risks. Public health authority input is not usually needed. However major emergencies that involve the release of a toxic cloud can result in health effects in the exposed general population beyond the boundaries of the site of the emergency as the disasters in Bhopal [5] and Seveso [6] demonstrated. Major emergencies involving chemicals can give rise to three categories of health effect: physical injury due to the accident itself, toxicological effects due to exposure to a noxious substance, and psychological stress or medically unexplained symptoms.

There is little or no provision in existing major emergency plans for assessing the risk to public health arising from a chemical incident or dealing with this risk. Dealing with the site of the major emergency will rightly be the focus of the first responders. It can be anticipated that the first responders at the site of a chemical incident might overlook the wider consequences for public health. This has been obvious in local exercises of the Seveso site external emergency plans. The protection of public health has to be built into major emergency plans for chemical incidents. In these situations, the first responder role needs to extend beyond the actual emergency site.

In the Seveso incident of 1976, chloracne, a skin condition was the acute effect seen in exposed local residents. Follow-up studies of public health status in the exposed population have confirmed the long-term toxicity involved. This toxicity involved cancer effects, cardiovascular effects, endocrine effects and reproductive effects [6]. In the Bhopal incident of 1984, over 3800 people died acutely. Long-term health effects: ocular lesions, respiratory impairment, significant neurological, reproductive, neurobehavioral and psychological effects persist in the surviving exposed population [5]. Public health protection will depend on the fire services to issue advice to shelter-in-place whenever there is any emission to air involving a potentially hazardous substance.

The fireworks depot explosion in Enschede, Netherlands is associated with persisting medically unexplained physical symptoms (MUPS) in the surrounding population. MUPS is associated with impaired emotional and physical functioning and is widely documented internationally in the aftermath of disasters, either natural or manmade. The patients often ascribe their symptoms to hazardous exposure. Timely full information can help to allay public anxiety and limit psychological stress [7]. In these situations, the early involvement of the public health authority is desirable. The first responders need to alert the public health authority.

As a result of the Dutch experience, the Dutch Ministry of Welfare, Public Health and Sports set up the centre for health impact assessment of disasters at the National Institute for Public Health and Environment to facilitate and prepare epidemiological studies after disasters. The role of the public health physician in the response to a major emergency where members of the public have been exposed to a hazardous substance involves (1) identification of the population exposed (those injured, those potentially harmed who may need health surveillance, and those who are unharmed or who may experience transient effects and who need full information); (2) assessment of the risk to public health (both the acute and chronic toxicant effects due to exposure to a noxious substance); (3) risk communication and guidance to key health professionals; and (4) risk communication to the public to address their concerns.

For public health risk assessment following a major emergency involving a chemical emission the resultant plume needs to be characterised. The dispersion model used would need to provide the required information to inform public health action to protect population health.

2.2. Approaches to setting a public safety zone around chemical incidents

In the event of a catastrophic release at a top tier Seveso site the generation of a toxic cloud is likely. The Seveso II Directive Article 13 (1) provides for the designation of an area specific to each individual top tier site whereby the operator of an establishment shall inform persons (other than persons working at an establishment) who are likely to be habitually in the area of the safety measures and of the correct behaviour, which should be adopted in the event of a major accident. The directive does not set out how to determine the extent of the specified area except as that area likely to be effected in the event of a major accident happening at the establishment. The specified area is determined by the operator concerned with the agreement of the competent authority or, where the operator concerned and the competent authority are not in agreement, by the competent authority.

Practice differs among EU countries. Some use a risk-based approach and others a consequence-based approach to setting the specified area.

For emergency planning there are a variety of approaches being taken to delimit the area(s) of risk due to a toxic cloud release. As part of ACUTEX, a EU funded research project, a survey of the competent authorities of all then existing 15 EU member states was done. It showed inter-country variation in approach, with a list of nine different acute exposure values being variously used in Seveso II related work [8].

In the UK the Emergency Planning Society and the competent authority have a memorandum of agreement put forward for discussion, which suggests that detailed planning will be based on the specified area[1] but it provides for an extended area [9]. As the UK regulations explain, the specified area "is set on the basis that people outside it are not at significant immediate risk from major accidents, although they could be if the accident escalates". The memorandum of understanding goes further and provides for a locally agreed extended area of risk for emergency planning. The extended area should be defined in the external emergency plan although it is not a pre-requisite that such an area should extend to "worst case scenario" distances identified in the safety report. It will depend on an assessment of the level of risk of harm and the probability of occurrence of the event. The extended area can be set by distance as agreed with the operator or by "community", i.e. taking account of the next defined settlement beyond the detailed planning area. The memorandum of understanding does not set out how either the specified area or the extended area is to be decided.

In Ireland, the competent authority has set out how it proposes to determine the specified area [10]. It proposes a consequence-based approach [11] even though the risk of occurrence could be extremely low. For toxic releases it proposes to use the distance to 1/2 the 30 min Dangerous Dose [12] for the release of a cylinder or drum of pressurised toxic gas over 10 min, under D5 weather/stability conditions, which occur for about 80% of the time. This proposal accepts that a 1% mortality rate might apply in "highly susceptible people" should the worst-case scenario arise. The approach limits consideration to acute effects. The Irish competent authority recognises that the emergency planning area might be different.

In Belgium the Crisis & Emergency Management Centre (CEMAC) [13] a non-profit organisation, was tasked in 2003 by the Belgian ministry of the interior with developing new software for chemical atmospheric dispersion modelling. CEMAC propose, based on a literature study and international best practice, to adopt the following chemical concentration sequence to determine the acute exposure limits:

- AEGL [14] (Acute Exposure Guideline Levels)
- ERPG [15] (Emergency Response Protective Guidelines)
- TEEL [16] (Temporary Emergency Exposure Limits)

The Swedish Rescue Services Agency is developing a zoning system for emergency planning. The definitions of the three zones are based on the need for personal protective equipment. The limit of each zone will depend on the concentration of the chemical in the air compared to Immediately Dangerous to Life and Health (IDLH) [17] values (personal communication). The IDLH is an occupational guideline and the zoning represents occupational health and safety procedures. The Swedish zoning system does not set out to protect potentially exposed general public or to categorise the nature of risk to public health involved in each zone.

The USA, Canada and South America are co-ordinating emergency reactions and have agreed that ERG 2004, the Emergency Response Guidebook, be universally recognised across that trading block [18]. The modelling software Areal Location of Hazardous Atmospheres (ALOHA) and Computer Aided Management of Emergency Operations [19] (CAMEO) are the basis for ERG 2004. In the latest version of ALOHA, the 60 min AEGL is the default level of concern [20]. In the absence of an AEGL for the chemical involved then ALOHA will default to the ERPG, TEEL or IDLH in that order [21].

2.3. *Approaches for assessing the health effects of toxic cloud releases*

The use of small caged birds in coalmines was one of the first attempts to detect toxic atmospheres, the proverbial 'canary in a coalmine'. The canary would succumb to the toxic atmosphere. The alert miner would recognise the need to escape. Domestic smoke alarms serve a similar purpose.

For epidemiological studies of health status in the aftermath of chemical incidents approaches used to estimate population exposure have included wind direction, local topography, effects on flora or fauna, and/or reported health effects. In Bonnybridge, in central Scotland, there was an investigation into human twinning rates following reports of increased numbers of twin births in cattle alleged to result from exposure to incinerator emissions containing dioxins. The area of highest risk was hypothesised to be the postcode areas downwind of the easterly winds, which are associated with sluggish airflow and temperature inversions. The area of secondary risk was hypothesised as the postcode areas downwind of the more prevalent and vigorous southwesterly winds. In addition surface soils were tested for the presence of PCH [22]. In a second study into low sex ratios of births, the areas at risk of air pollution were identified a priori through four types of assessment (i) the probable effect of wind direction and strength on dispersion, (ii) the effect of local topography, (iii) anecdotal reports on residents of nuisance from plumes and (iv) soil test results for the presence of air pollution contami-

[1] The specified area is called the public information zone in the UK regulations.

nants [23]. In Seveso in Italy the area and population exposed to the emission was identified by the presence of soil contamination with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The presence of early symptoms such as chloracne was used to identify the most heavily exposed and abnormal liver function tests were another indicator of exposure. Effects on flora and fauna [24] were also used to delimit the area of concern.

2.4. *Emergency preparedness for health effects of toxic cloud releases*

To select the appropriate level of concern or threshold for the protection of public health in the event of a catastrophic release, the parameters to consider include the characteristics of the population potentially exposed, the nature of the health concerns and the likely time period of exposure.

The population we are concerned about in the event of a toxic cloud release from a Seveso II site is the general population. The chosen threshold should protect all members of the population including persons who may be more sensitive to toxicological effects. Age, health status and exertion influence how susceptible one is to a pollutant. The limits set for the workplace environment may underestimate risk to the young, the elderly and those with chronic ill health. On the other hand workplace limits do incorporate safety factors and may be overly protective for the catastrophic release situation given that the duration of exposure is likely to be short.

The public health authority and the emergency responders need to plan to manage the full range of possible health effects from acute toxicity, to long-term effects, to the public anxiety that might result from the mere perception of the odour associated with a release. The level of concern chosen should reflect the full range of potential health effects.

The time period of exposure is a function of how long the release continues and the environmental fate of the emission once released. Emergency planners in the EU and US propose to plan for a 10 min scenario. The assumption is that either the entire volume of substance in a catastrophic release will vent in 10 min or the operator or emergency first responders will take action to stop the release by 10 min. A 10 min catastrophic release represents a worse case scenario than a release over a longer time period. Where hazardous substances are concerned concentration of exposure is more significant than time. A shorter exposure time to a higher concentration will usually result in more severe effects than exposure to a lesser concentration over a longer time period.

The extent of the emission is influenced by the weather conditions at the time, the topography or contour of the site and the surrounding area, and the actual physics of the substance in the release. However gas clouds do follow a predictable fate. East winds are associated with the grounding of plumes. Inversion weather conditions result in delayed dispersion and accumulation over time leading to an increase in concentration with continuing release of hazardous substance. In the London fog of 1952, inversion weather conditions led to extremely high levels of air pollution leading to several thousand excess deaths during the week of fog [25]. If one has information on the release and on the weather conditions at the time, this information can be fed into appropriate air dispersion modelling software. The resultant gas cloud can be well approximated.

2.5. *Air dispersion modelling for emergency preparedness*

A number of air dispersion models are reviewed. ALOHA, Areal Location of Hazardous Atmospheres [26] is available from the US Environmental Protection Agency and is intended for use by first responders for pre-planning and in emergency response. It has been rigorously developed and validated. In the emergency response situation, simply entered prevailing weather information is fed into the model along with the identity of the substance released with a best estimate of the amount of the release. One can manually input data on wind speed and direction, wind measurement height, ground roughness, cloud cover, air temperature, inversion height (if a low level inversion exists), and relative humidity. The model selects the best fit on stability class from the information inputted. An override option is available. Else, one can connect a portable meteorological station to the computer to input the weather conditions. A level of concern or threshold can be chosen. ALOHA uses this information in conjunction with physical property data from its extensive chemical library that covers over 700 pure chemicals. ALOHA can predict rates of chemical release from broken gas pipes, leaking tanks, and evaporating puddles, and can model the dispersion of both neutrally buoyant and heavier-than-air gases. It addresses buoyancy conditions from inversion to gale force winds. A limitation of ALOHA is that it is two-dimensional and does not take topography into account. It will model true chemicals and not compounds. Advantages of ALOHA are that it is freely available, is easy to use and provides a rapid output.

Det Norske Veritas of Oslo, Norway (DNV Technica) produce a commercially available tool, the Process Hazard Analysis Software Tool (PHAST). The model used, the unified dispersion model, has been well validated. The tool is use to model boiling liquid expanding vapour explosions (BLEVEs), jet fires, pool fires and vapour cloud explosions. It can handle multicomponent mixtures. The tool SEVEX (Seveso Expert) [27] was developed in Belgium with research funding. It is now available commercially. It is a three-dimensional model and has strength in looking at inversion weather conditions. A Belgian model RIMPUFF and a Danish model DERMA are generic atmospheric dispersion models, the outputs of which can be used to predict dispersion of any material assuming appropriate knowledge of its chemical and physical properties. RIMPUFF [28] is described as mesoscale, covering dispersion up to 150 km. The DERMA model is long range continental. For chemical incidents the more appropriate model would seem to be RIMPUFF.

DEMA, the Danish Emergency Management Agency and Prolog Development Centre, a Danish software company, developed ARGOS, a decision support system for major emergencies. It defines input parameters for the models and one can visualise the results on geographical maps. One has to input: what is released, the heat of the release, the height of the release, when the release occurred and the duration of the release. ARGOS incorporates other models (for instance, a radioecology model for estimating the radioactive dose from ingestion of contaminated foodstuffs) and also features tools to view and analyse monitoring data. A consortium involving agencies from a number of countries including Denmark, Sweden, Ireland and Canada manage the strategy and ongoing development of the software. A sister product, ARGOS C [29], is currently being developed in order to provide decision support for chemical incidents. This will feature the same models and visualisation applications mentioned above. It will also feature a new module for modelling releases in an urban environment.

ALOHA is freely available, has been validated and is easy to use. It can be loaded onto a standard personal computer. In drawing up the external emergency plan one is planning for a low probability event. The actual event, should it occur, will undoubtedly differ from the scenario detailed in the external emergency plan. When the incident occurs and the real detail is available then is the time to refine your estimates and to use the 3D models to improve the precision of the public health risk assessment. It is valid to use the best 3D air modelling tools available to model predicted regular emissions from a plant for example at the planning or licensing stage. Costs are greater for the newer 3D models and this will limit their application. The application of 3D models is not required for Seveso site external emergency planning purposes.

2.6. Air dispersion modelling for emergency response

The degree to which air dispersion modelling is used by first responders in emergency response is not known. Certainly it is not the normal practice in Ireland. Few are trained or experienced in the use of ALOHA or a similar software plume modelling tool. The technology is not available to all fire services let alone all fire crews involved in the emergency response. Furthermore the first responders to the scene do not necessarily see it as their role to provide information that is needed for the post-emergency response follow-up. In emergency response another arrangement might be needed.

In the UK, it is the responsibility of the meteorological service to produce what is termed a CHEMET [30] and the map of the plume. In the event of a chemical release the meteorological service provides a detailed forecast for the site and runs a dispersion model to produce an "area at risk" template, which is then overlaid on a 1:15,000 Ordnance survey map for the area of the affected site. Two in-house developed dispersion models are used. The agreed response time is 20 min. The initial basic emergency response uses a simple 2D Gaussian model, the Atmospheric Dispersion Model System (ADMS). It is based on a unit release of 1 g/(m^3 h) of a neutral chemical, and the meteorological data. The information informs decisions on shelter and/or evacuation. At a later time when there is more information on the chemical and the circumstances of the release, the areas at risk can be refined. An in-house developed 3D dispersion model NAME [31], which takes the contours of the site and surrounding area into account, is used for this purpose. The UK Met Office is a member of the World Meteorological Organisation (WMO). It is a regional specialised meteorological centre (RSMC) for emergency response and a world area forecast centre for aviation. RSMC Exeter and RSMC Toulouse have joint responsibility for environmental emergency response requirements in WMO regions VI and I that covers Africa and Europe. RSMCs exist to provide advice in the event of a nuclear accident.

2.7. Level of concern or acute exposure value

The level of concern or exposure limit is a threshold concentration of an airborne pollutant, usually the concentration above which a hazard to people is believed to exist. The exposure limit is expressed as a specified concentration over a set time period of measurement and for a defined population group. Exposure limits have been established by government agencies and professional organizations to safeguard the health of workers and the public from hazardous atmospheres. The main exposure guidelines are reviewed on the CAMEO toolkit level of concern page [32]. Occupational exposure limits such as the Threshold Limit Values (TLV) [33] or Permissible Exposure Limits (PEL) [34] are deemed acceptable for most adults for an 8 h workday, for a lifetime of employment.

The levels of concern most appropriate to emergency planning to protect the public from a toxic cloud release are reviewed. From a public health perspective the important thing is to know the definition of the level of concern, how it was derived and for what purpose.

2.7.1. Immediately Dangerous to Life and Health (IDLH)

The National Institute for Occupational Safety and Health (NIOSH) established the Immediately Dangerous to Life and Health (IDLH) [17] limit. It is based on conditions that pose immediate danger to life or health. The methodology uses an exposure time of 30 min. Workers should not be in an IDLH environment for any length of time unless they wear appropriate personal protective equipment. The values were determined based on animal and human data.

2.7.2. Emergency Response Planning Guideline (ERPG)

The American Industrial Hygiene Association developed the ERPGs [15]. The ERPGs are three-tiered guidelines with the common denominator of a 1 h contact duration. Each ERPG guideline identifies the substance, its chemical and structural properties, animal toxicology data, human experience, existing exposure guidelines, the rationale behind the selected value and a list of references. So in any situation it is useful to seek the ERPG for the substance, as it will provide detailed information on the substance concerned. Hypersensitive individuals would suffer adverse reactions to concentrations far below those suggested in the ERPG guidelines. ERPGs are based mostly on animal studies raising the question of applicability to humans. Also the ERPG committee strongly advises against trying to extrapolate ERPG values to longer periods of time. The ERPG does not include safety factors usually incorporated into exposure guidelines but rather estimate how the public would react to chemical exposure. Just below ERPG-1 most people would detect the chemical and may experience temporary mild effects. Just below the ERPG-3 on the other hand it is estimated that the effects would be severe, although not life-threatening. The

ERPG should serve as a planning tool not as a standard to protect the public health. ERPG-2 is used by the Emergency Response Guidebook to prepare recommended isolation and evacuation distances.

2.7.3. Temporary Emergency Exposure Limit (TEEL)

TEELs [16] or Temporary Emergency Exposure Limits are temporary limits of concern similar to ERPGs. The US Department of Energy has defined TEELs, which are to be used as exposure limits for chemicals for which ERPGs have not yet been defined. Like ERPGs they do not incorporate safety factors. TEELs are only approximations and are not based on careful analysis of experimental data, unlike ERPGs which are derived from extensive reviews of animal and human studies. They are derived according to a specific, standard methodology. The methodology prescribes using the ERPG when available, and when no ERPG exists, using available levels of concern and manipulating current data using a peer-reviewed, approved procedure. TEELs are three-tiered. TEEL-1 predicts irritation and other minor effects. TEEL-2 predicts irritating but reversible effects. TEEL-3 predicts serious impact with perhaps death of compromised individuals.

2.7.4. Acute Exposure Guideline Level (AEGL)

The Acute Exposure Guideline Level is a concept that developed in the mid-1980s as a result of the Bhopal incident. The US EPA, in accordance with a published rigorous methodology involving a thorough review of available human and animal toxicology data, draws up AEGLs [14]. Safety factors are included so AEGLs are designed to protect even the most sensitive members of the population. The AEGL is a short-term one-time (single) airborne exposure level. AEGLs are guideline values that represent three levels of health effect severity: AEGL-1, AEGL-2, and AEGL-3; and each is developed for five exposure periods: 10 min, 30 min, 1 h, 4 h, and 8 h. There is not a level 1 AEGL for all chemicals if the first effect seen is more appropriate as a level 2. As of early-2007, defined AEGL values for 191 chemicals have been released.

2.7.5. European Acute Exposure Threshold Levels (AETL)

Under Community Research and Development Information Service (CORDIS), an EU funded project ACUTEX set out to define a methodology, software tools and a technical guidance document for establishing European Acute Exposure Toxicity Thresholds (EU AETLs) in the event of an accidental chemical release. The project has derived AETLs for 20 substances. The results [8,35] and the methodology are published [36].

2.8. Selection of level of concern

The AEGL and ERPG specify a contact time. For the ERPG the contact time is 1 h and it is not recommended that one extrapolate for other contact times. Other contact times are available for the AEGL. TEEL does not specify a contact time. All are three-tiered guidelines. ERPG and TEEL do not incorporate safety factors but rather predict how those exposed will react to the chemical. All three guidelines are derived according to a peer-reviewed and approved methodology. The hierarchy of the evidence base for the guideline is higher for the AEGL than ERPG.

In setting a methodology for responding to toxic clouds we are recommending that one use the 10 min AEGL if available as the default level of concern, otherwise use the ERPG. When neither AEGL nor ERGP is available use the TEEL. It is not recommended nor is it clear how one could derive a 10 min value for the ERPG. Rather the public health physician has to be aware of the limitations of the measurements and the standards considered and make decisions in the light of an understanding of the limitation of the approach. For example, using the ERPG, by definition the contact period is 1 h, to delimit the area of concern will enable one to identify the population exposed and the nature of health effects they may experience. If the time period of exposure is less than 1 h then the health effects experienced by the exposed public is likely to be of lesser severity than that expected as per the ERPG entailing 1 h of exposure. Similarly if the time of exposure is greater than 1 h then the health effects experienced by the exposed public is likely to be more severe than that expected as per the ERPG entailing 1 h of exposure.

Sequentially using the three levels of concern available in the AEGL in ALOHA will yield a gas cloud schema similar to Fig. 1, the combined result of the three dispersion plume footprints. The information, from the three dispersion plumes footprints, is used to identify the hot, warm and cold zones as set out in text Box 1 . The footprints can be used to identify different cohorts or populations from the public health perspective, as outlined in text Box 2 . When the 10 min AEGL-1 is used as the level of concern in the modelling software, the resultant dispersion plume delimits the "cold" zone. This area delimited by AEGL-1 defines the population who may be concerned about

Box 1. Definition of the hot, warm and cold zones for the first responders

Hot zone: airborne concentrations above which the general population could experience life threatening health consequences or death.
Note: full protective equipment and clothing required as per Hazchem Code, Chem.
Primary action: casualty handling
Warm zone: airborne concentrations above which the general population could experience irreversible or other serious effects.
Note: access point into hot zone. Decontamination area for the emergency services.
Primary action: casualty handling
Cold zone: airborne concentrations above which the general population could experience notable, non-disabling, and reversible effects.
Note: contains control and command post and other support functions.
Primary action: public information

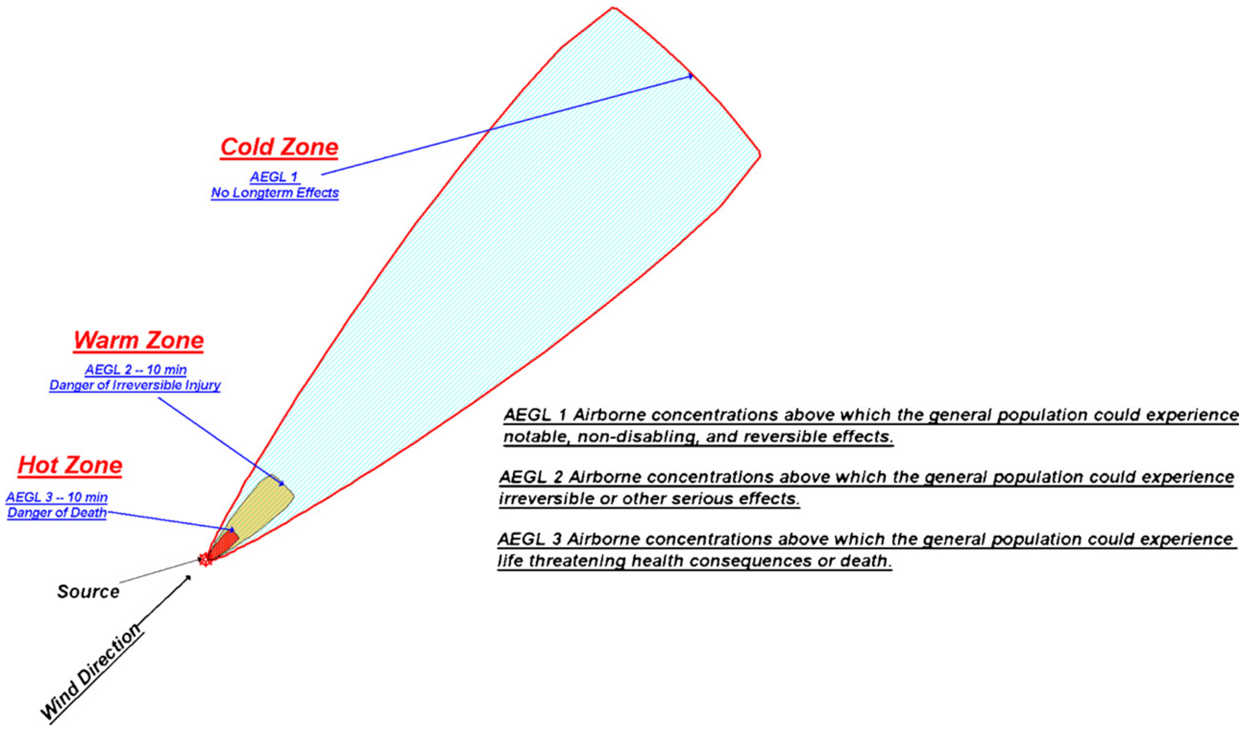

Fig. 1. Typical gas cloud dispersion plume schema using ALOHA.

Box 2. AEGL definitions with the public health significance of the hot, warm and cold zones

AEGL 1: the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

Public health significance: AEGL 1 delimits the area of public concern.

Zone: this area is referred to as the cold zone (see Table 1).

AEGL 2: the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape.

Public health significance: AEGL 2 delimits the area where population might be included in long-term surveillance or be recruited into a cohort study.

Zone: this area is referred to as the warm zone in Table 1.

The 10 min AEGL 2 is the default on ALOHA 5.3.

AEGL 3: the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Public health significance: AEGL 3 delimits the population that may require the assistance of the acute medical services.

Zone: this area is named the hot zone in Table 1.

being exposed and who need full information based on comprehensive risk assessment. The 10 min AEGL-2 as level of concern is used to define the limit of the "warm" zone. AEGL-2 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long lasting adverse health effects or an impaired ability to escape. By definition persons exposed to concentrations above the level of AEGL-2 need follow-up. The area delimited by AEGL-2 defines the population for long-term surveillance or a cohort study when indicated. This population may include some first responders. The dispersion plume obtained by using the 10 min AEGL-3, the new default set on ALOHA 5.4.1, as the level of concern in the modelling software provides the limit of the "hot zone". This area delimited by AEGL-3 defines the population who may present acutely to the medical services for investigation and treatment.

2.9. The worst-case scenario from the safety report as the best basis for the external emergency plan

It is a generally held principle that emergency plans should now take account of the full range of possible major accident scenarios at an establishment whilst also ensuring the degree of planning is proportional to the probability of the accident occurring. The safety report for each site is a requirement under the Seveso II directive and it outlines the nature of the possible accident risks that exist on the top tier site along with the measures that are being taken to minimise each risk. The safety report is examined and the worst-case scenario in terms of potential loss of life or serious health effects in those exposed should a catastrophic failure occur is identified. The method uses this worst-case scenario, and the chemical involved, as the basis for drawing up the first version of the site external emergency plan. With the chemical identified, the 10 min

AEGL sets the planning distance. ALOHA delimits the hot, warm and cold zones. In emergency planning using ALOHA weather conditions have to be entered. Either of two approaches is acceptable. One can model a range of weather conditions and select the model that results in the worst outcome or alternatively one can chose to input and model the most prevalent weather conditions.

3. Results

3.1. External emergency plan

Annex IV of the directive specifies the data and information to be included in the emergency plans. The external emergency plan is to include information that identifies the authorised persons to set the plan in motion and persons authorised to take charge and co-ordinate off-site actions; set out the early warning, alert and call-out arrangements; specify the external plan resource coordination arrangements; the arrangements for providing on-site assistance, the off-site mitigatory arrangements; the arrangement for the provision of information to the public; and the arrangements for the provision of information to emergency services of other member states where possible trans-boundary consequences could exist.

The Cork Joint Emergency Planning Group (CJEPG) external emergency plan gives the name and location of the establishment, sets out a table on contents and a record of (i) issue date and amendments, (ii) exercise and review record, (ii) issue date of the internal emergency plan, and (iv) the distribution list. The table of contents is set out in text Box 3 .

Box 3. Table of contents of external emergency plan

Contents, records and circulation

1. Background information
   - Purpose and scope
   - Arrangements for mitigation
   - Company background
   - Major accident scenarios
   - Aerial view
   - Site layout
2. Activation and stand down
3. Response to activation
   - By operator
   - Police
   - Health authority
   - Fire and rescue service
   - Relevant others, e.g. airport or port authority
4. Public safety zone (PSZ)
   - Worst-case scenario.
   - Hot and warm zones (PSZ)
   - Police control points.
5. Procedures of the emergency services
   - Fire and rescue service
   - Police
   - Health authority
   - Relevant others if applicable
6. Site environment
   - Population
   - Surrounding area
   - Surface water and fire water containment
7. Appendices

   Appendix 1: extracts of legislation

   Appendix 2: emergency services pre-planning form

Detailed information on:

- Construction details and description of buildings on site.
- Occupancy details including details of persons to be contacted in the event of an emergency.
- Details on the risks existing on site.
- Details of all mitigatory resources available on site.
- Location and site maps.

- Appendix 3: public health statement for chemical(s) of worst-case scenario.
- Appendix 4: public information leaflet.
- Appendix 5: press statement in the event of major incident.

3.2. The public safety zone

The public safety zone is defined as follows. The external emergency planning area is that area that could be affected by an incident. The public safety zone (PSZ) includes addressing low probability scenarios. These incidents will however be of high consequence. In the unlikely event of an incident occurring, there will be casualties with varying degrees of injury within the PSZ. The danger will vary according to the distance from the incident. In the immediate vicinity of the incident, the danger will be highest, and injuries could be fatal. Further away the danger of fatalities would be small, but there is still a high probability of injury. Outside of this area is a zone within which there is a small possibility of injury. These are reflected within the PSZ zones, that is, the hot zone where there is a high probability of injury leading to death. The warm zone where there is a real possibility of serious harm. The cold zone where there is a low probability of injury. The 10 min AEGL 3, AEGL 2 and AEGL 1 will delimit the hot, warm and cold zones, respectively. The Cork Joint Emergency Planning Group proposes to use the computer program ALOHA to model the worst-case scenario agreed between the national com-

Table 1
Thermal radiation thresholds

Thermal radiation level (kW/m^2)	Effect on bare skin
2	People will feel pain after 45 s and receive second-degree burns after 3 min
5	People will feel pain after 13 s and receive second-degree burns after 40 s
10	People will feel pain after 5 s and receive second-degree burns after 14 s
20	Timber will spontaneously ignite

petent authority and the site operator and set out in the safety report.

The methodology can be adapted to suit explosive risk and response to fire as shown in the following examples.

3.2.1. Example 1. The public safety zone around a fireball/thermal radiation

The area around the fireball where the degree of heat over the time involved would result in 2nd degree burns or more represents the hot zone. The warm zone is the area within which the degree of heat by the time involved could cause 1st degree burns or blistering of the skin. Within the cold zone the degree of heat by the time involved might result in the perception of pain. Table 1 shows thermal radiation burn injury criteria [37].

3.2.2. Example 2. The public safety zone around an explosion

The overpressure associated with minor damage to house structures would delimit the hot zone [38]. The warm zone is the area within which the overpressure could result in effects from window breakage to minor damage to house structures. Within the cold zone some might complain of loud noise effects.

3.2.3. Example 3. The public safety zone around a boiling liquid expanding vapour explosion (BLEVE)

A BLEVE might result in (1) a fireball; (2) thermal radiation; (3) explosion or blast injury; and (4) projectiles and shrapnel. The hot zone is defined as four times the fireball radius. The warm zone is defined as the area subject to 90% of the projectiles from the cylindrical storage tank. When a cylindrical tank explodes, the area around the tank might be considered in four equal zones, two end zones and two side zones. Two-thirds of the projectiles will fall in the end zone. The remaining third of projectiles will fall in the side zone. In a study of 400 l propane tanks most (80%) projectiles landed within 50 m on either side of a line drawn through the tank axis. However, some projectiles fell well out of this zone [39]. The possible travel distance of a tub rocket defines the cold zone empirically. In Mexico city [40] this distance was 1200 m.

The local public health department has developed in-house site-specific emergency packs to inform public health decision in the event of a major incident arising on the site. The pack contents are listed in text Box 4 .

Box 5. Public health authority emergency file for each Seveso site: pack contents

1. Description of the facility.
2. Directions to the site.
3. Maps of the site and surrounding area.
4. External emergency plan for the site.
5. Synopsis of the safety report detailing the potential accident scenarios.
6. Health Protection Agency Essential Chemical Safety Information sheets &/or Company Material Safety Data Sheets for main substances used/produced.
7. Products of combustion information.
8. Occupational health monitoring/screening information.
9. Lessons learned from desktop exercises.
10. Reference to the site integrated pollution control licence from the Environmental Protection Agency.
11. Reference to the environmental impact statement (EIS)—where stored. An EIS is prepared at the pre-planning/site development stage as a requisite to planning/development permission. In the aftermath of a major incident it can serve as a baseline of pre-incident environmental conditions.
12. Reference to Health Protection Agency checklists available to aid decision making, e.g.

(a) Products of combustion.
(b) Evacuation or shelter.

4. Conclusion

The EU Seveso directives aim to prevent major accidents from certain industrial activities. When major accidents occur the directives aim to limit the consequences for man and the environment. The aim is to protect human health through preventative action. Using site-specific information on the nature of the risk involved, the external emergency plan is to guide first responder action to protect public health. The first responders need to be aware that effective public health action is facilitated by their actions. From the public health perspective an approach is needed that will seek to prevent all potential health effects in exposed population including long-term health effects and public anxiety.

This paper outlines a methodology for determining the public safety zone for toxic cloud emissions from Seveso II sites. Proportionality is needed in emergency planning. The paper has considered why use of the specified area as the basis for the development of external emergency plans is not sufficient for the protection of public health. The model proposed considers the worst-case scenario outlined in the safety report as the basis for drawing up the external emergency plan. The operator and the competent authority have to agree the scenarios and the worst-case scenario in the safety report. The credible worst-case scenario is identified on the basis of quantitative risk analysis taking mitigation measures and probability of occurrence into account. The hazardous substance identified in the worst-case scenario is dealt with in detail by the external emergency plan. The plan needs to use the right threshold or limit value so as to protect public health. Identification of the threshold to use involved consideration of the behaviour of gas clouds, the population at risk and the available levels of concern, their definitions and evidence base. In terms of public health AEGLs are the most authoritive resource available, followed by the ERPG and then the TEEL. The public health approach does not include an acceptable mortality rate.

It is important to model the worst-case scenario, to put it up on maps (using a geographical information system) using the best possible information on the hazard (AEGL) and the best software model available (ALOHA). The public health significance of the hot, warm and cold zones is explained.

This paper outlines a methodology that would identify an extended area of risk and an emergency plan for all probabilities. The first responders following the emergency plan would work from the limit of the extended risk area in towards the site. It would ensure that the first responders would not find themselves in an unsafe situation from which they might need to retreat. On activation the first responders will report to the pre-identified rendezvous point and the police will establish the public safety zone. The fire officers will investigate and decisions will be based on factors such as the prevailing weather conditions and further information from the plant. For example information may emerge that the leak is now sealed and the emission is stopped, or a less hazardous material was involved, or the tank was half empty so less has been released.

It is essential that the external emergency plan is conservative. Else the alternative, representing a valid concern, is that first responders will be in a location of danger and will only discover this when they arrive, leading to retreat. This would immediately result in chaos and the plan would fall apart. Once the site external emergency plan provides for the worst-case scenario, future updates of the off-site plan can incorporate the response for lesser incidents involving hazardous materials outlined in the safety report.

Tests of the off-site plan are important as lessons will be learned which will lead to more robust and useful plans.

To respond to an actual incident the emergency planning tools needed are the correct threshold value for the protection of public health and the appropriate software for modelling the gas cloud. The plant operator will need to supply as accurate as possible information on the hazard involved. The first responder needs to interpret the information received concerning the incident along with information on prevailing weather conditions to arrive at the correct model forming the basis for the emergency response.

The protection of public health is inherently built into the plan by the selection of suitable levels of concern. Emergency planning needs to be done in an open and transparent fashion. The Seveso directive requires public consultation. A standard methodology facilitates discussions with both the plant operators and the general public living in the vicinity of the plant. In setting the distances to protect public health it ensures that the emergency responders also site themselves in a safe area.

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