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Review

Managing mass casualties and decontamination

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ABSTRACT

Careful planning and regular exercising of capabilities is the key to implementing an effective response following the release of hazardous materials, although ad hoc changes may be inevitable. Critical actions which require immediate implementation at an incident are evacuation, followed by disrobing (removal of clothes) and decontamination. The latter can be achieved through bespoke response facilities or various interim methods which may utilise water or readily available (dry, absorbent) materials. Following transfer to a safe holding area, each casualty's personal details should be recorded to facilitate a health surveillance programme, should it become apparent that the original contaminant has chronic health effects.

Contents

1. Introduction

Whilst relatively uncommon, incidents involving the exposure of large numbers of people to chemical, biological or radiological materials do occur (Table 1). In general, chemical incidents tend to be more time critical, especially for substances that have a rapid onset of effect, thus it is important that any "all hazards" response plan can be implemented quickly and efficiently.

Mass casualty events highlight the need to ensure that first responders have both the training to recognise incidents and the available resources to mitigate the health effects of exposure to toxic materials (Bradley, 2000; Burgess et al., 1999; Simon, 1999; Totenhofer and Kierce, 1999; Tur-Kaspa et al., 1999). The potential impact of such incidents has led many governments and international organisations to review existing response arrangements and to develop, where necessary, new and improved procedures for dealing with major incidents. The aim of this paper is to review and summarise common features and problems inherent to mounting an effective response in order to limit or prevent health effects arising from exposure to hazardous substances.

2. Time constraints

Hazardous materials are broadly categorised into three groups: chemical, biological or radiological (Thornton et al., 2004) and reviews

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Table 1
Examples of mass casualty incidents involving, radiological, chemical and biological contaminants.

Incident type	Contaminant	Summary	Reference
Radiological	Caesium	Four fatalities and contamination of ~250 people following exposure to a stolen ^{137}Cs radio-therapy device in Goiania, Brazil (1987).	Roberts (1987)
	Mixed radionuclides: caesium, strontium, plutonium, iodine, tellurium, xenon, etc.	Approximately 30 deaths due to acute radiation exposure following an accidental explosion at a nuclear power station in Chernobyl, Ukraine (1986). Probably an excess of one million exposed. True incidence of long-term health effects not yet established.	Saenko et al. (2011), Anonymous (2010a, 2010b)
Chemical	Sarin	Deliberate release of sarin (a nerve agent) on Tokyo underground (1995). Twelve fatalities and several thousand potentially exposed.	Tokuda et al. (2006)
	Methylisocyanate	Exposure of 200,000 local residents following accidental release at chemical factory in Bhopal, India (1984). Over 3000 fatalities. High incidence of chronic health effects in survivors.	Dhara (1992)
Biological	Anthrax	Accidental release of anthrax spores from military establishment in Sverdlovsk (Yekaterinburg), Russia (1979). Possibly 66 fatalities, total affected unknown.	Cieslak and Eitzen (1999)

of relevant materials are presented elsewhere (Chilcott, 2010; Gupta, 2009; Marrs et al., 2008; Maynard and Chilcott, 2009). Whilst radiological and biological contaminants are clearly of concern, exposure to chemicals will often require more rapid clinical intervention to mitigate potential health effects. For example, inhalation of nerve agents and hydrogen cyanide may be lethal within minutes in the absence of appropriate antidotes (Maynard and Chilcott, 2009). In contrast, there may be a potential therapeutic window of several days or more for the effective administration of medical countermeasures against biological or radiological contaminants. Therefore, chemical exposure presents a different chronological challenge to incidents involving radiological or biological materials. Ideally, chemical incident response timescales should be considered the minimum approach for all-hazards response planning. In recent surveys of emergency response organisations within the European Union (Baker, 2010; Meineke et al., 2010), the time required to deploy a decontamination facility for chemical or radiological incidents were reported to be in excess of 10 h for 20–30% of respondents, with 15–20% of respondents indicating no national capability (Fig. 1). These data suggest that preparedness for mass casualty incidents involving hazardous materials is some way short of ideal.

In order to achieve minimal response times, lessons could potentially be learnt from military doctrine derived from decades of research, development and operational experience. However, there are many considerable and necessary dichotomies between military and civilian preparedness: the former tend to involve healthy, trained individuals who may carry appropriate (detection, protection, decontamination and medical) equipment on their person and may have received prophylactic therapies such as nerve agent pre-treatments (Newmark, 2007) or vaccines (Ramasamy et al., 2010). Consequently, a military response to a hazardous material incident is likely to be swift and effective. In contrast, there will necessarily be a delay between initial exposure and on-scene arrival of appropriate equipment, countermeasures

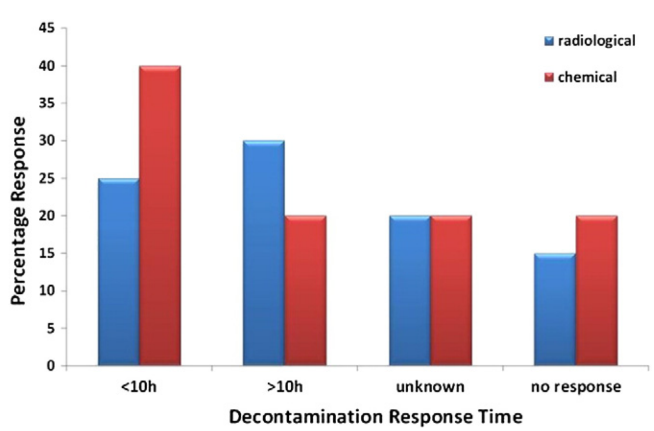

Fig. 1. Decontamination response time results from a survey of EU Member States Countries performed as part of the "mass casualties and healthcare following the release of toxic chemicals or radioactive material" project (Baker, 2010; Meineke et al., 2010).

and trained personnel during an incident involving exposure of civilians. Thus, whilst some military practices can be applied to civilian incidents, the two are generally incongruous.

It cannot be assumed that all civilian casualties will have the physical or cognitive ability to comply with instructions or procedures and there may be additional factors which may affect the overall effectiveness of an incident response (Table 2).

3. Incident recognition

It seems obvious to state that the 'trigger event' to mounting an effective incident response would be the recognition that actual (or potential) exposure to a hazardous material had occurred. Overt indications of environmental contamination may include fire, smoke, unusual odour(s) and obvious cues such as damaged containers labelled with hazard warning signs. In some instances, these initial cues may be absent: the Goiania incident is a case in point (Table 1). Thus, health effects may be the first indication of a mass casualty event.

Many irritant or toxic materials provoke acute health effects and so may quickly raise suspicion of an exposure. Conversely, other materials have a latent period during which pathological changes may develop in the absence of any clinical manifestations. In general, a 'silent' (or covert) inhalation exposure to biological and radiological materials may not elicit effects for a period of several hours to days (Dorr and Meineke, 2011; Ramasamy et al., 2010). This may also be the case for certain chemicals such as phosgene and sulphur mustard (Marrs et al., 2008; Maynard and Chilcott, 2009). The onset of health effects following exposure to chemicals which act predominantly via the percutaneous route, such as the nerve agent "VX" (Joosen et al., 2013) may also be subject to a latent period which will be dependent on the anatomical location of the exposure and the environmental conditions (Craig et al., 1977; Duncan et al., 2002; Hamilton et al., 2004).

In addition to having a rapid onset of effect, some materials also have well defined signs and symptoms of exposure ('toxidromes') which may provide a strong indication of the nature of the causative material (and thus antidote requirements). For example, substances which act via inhibition of acetylcholinesterase (such as pesticides and nerve agents) may produce nicotinic or muscarinic stimulation, resulting in miosis and hyper-salivation, respectively. Specific toxidromes have been used to develop algorithms to assist in the recognition of exposure to key threat agents (Cieslak et al., 2000; Heptonstall and Gent, 2006; Krivoy et al., 2005). However, it should be noted that only a relatively small group of chemicals have such characteristic toxidromes; the vast majority of chemicals and hazardous materials cause non-specific effects such as coughing, headache, nausea, vomiting, diarrhoea and dizziness.

The adequate training and exercising of first responders is vital in facilitating the process of incident recognition and many countries have developed appropriate procedures. In the UK for example, the police, fire and ambulance services have adopted an initial response based on

Table 2
Examples of factors inherent to the general population which may potentially reduce the ability of the emergency services to respond to a hazardous material incident.

Factor	Worst-Case Impact	References
Young age	Reliance on others to perform relevant procedures such as disrobe and decontamination.	Carter et al. (2013a), Fertel et al. (2009), Taylor et al. (2009), and Timm and Reeves (2007).
Old age	Reduced physical ability to comply with relevant procedures.	
Dementia	Reduced mental ability to comply with relevant procedures.	
Religion	Reduced compliance with disrobing or mixed gender decontamination due to modesty issues.	
Language	Reduced ability to understand instructions and guidance.	
Pre-exiting Disability	Reliance on others to perform relevant procedures such as disrobe and decontamination, impaired ability to follow emergency services' instructions.	
Pre-existing Medical condition(s)	Enhanced susceptibility to hazardous materials.	
Incident-related injury	Enhanced susceptibility to hazardous materials, impaired ability to follow instructions and reduced ability to perform relevant procedures.	

the “Safety Triggers for Emergency Personnel” or STEP 1–2–3 + procedure (Table 3).

In summary, incident recognition is the critical trigger for implementing an effective response and vigilance, experience, training and common sense are key factors.

4. Initial response

National or regional plans are in place in many countries for responding to mass casualty incidents arising from exposure to chemical, biological, radiological or nuclear (CBRN) materials (Annelli, 2006; Anonymous, 2010a,b; Baker, 2007). Whilst the details of such plans vary, they have generic features which this section will present in chronological order. It should be noted that the actual sequence of activities may be dictated by on-going risk assessments and availability of resources. Therefore, incident managers should be prepared for ad hoc changes to long-standing plans and have the presence of mind not to delay activities critical to reducing potential health impacts by doggedly adhering to written procedures.

The following review is based on the assumption that an incident has been recognised and that appropriately equipped responders are available on scene. Clearly, this is representative of an ideal scenario. In reality, life-saving actions may be required by first responders equipped with minimal levels of personal protective equipment (PPE) operating to country-specific guidelines such as the “3/30” rule (Anonymous, 1999) under which short-duration “snatch” rescues may be performed prior to the arrival of a specialist response.

4.1. Ambulant casualty evacuation

The primary (and rather self-evident) response to any incident should be to remove individuals from the source of exposure. For ambulant casualties, this should involve facilitating immediate self-extraction from the point of contamination to a safe location (ideally upwind, uphill and at a safe distance). Such an apparently simple step can present a number of practical problems due to inherent uncertainties regarding the source and/or location of the contaminant, one manifestation of which may be a difficulty in establishing the safe distance from the point of release or indeed to consider alternatives such as “shelter in place”. Such issues may be location-specific and so only resolvable at the time of an incident. A further factor to consider is that the location of the warm zone may need to be moved during the course of an incident to take into account changes in wind direction or the subsequent identification of additional hot zones.

4.2. Non-ambulant casualty evacuation

Non-ambulant casualties may arise through traumatic injury or pre-existing disability. The evacuation of such individuals may pose two problems. Firstly, serious injuries such as non-compressible haemorrhaging or spinal trauma may necessitate stabilisation of the patient prior to movement. Such injuries may present at incidents where hazardous materials have been subject to energetic (explosive) dissemination. However, evacuation would be a priority over stabilisation if the hot zone were to be overtly life-threatening.

Secondly, assisting non-ambulant individuals from the hot zone may entail a “snatch rescue” for which appropriate protective equipment would be required to prevent the rescuer from becoming a casualty. In the presence of an airborne hazard, it would be inappropriate for a responder to attempt a snatch rescue without some level of respiratory protection (for example, an “escape hood”). As the primary role of the emergency services is to save lives, this could pose a considerable dilemma, especially where non-ambulant hot-zone casualties are visibly distressed.

4.3. Identification of incident zones

During the evacuation phase, the outer area peripheral to the incident should be cordoned off to prevent accidental exposure of unaffected individuals to the contaminant. The distance from the contaminant source to the outer cordon varies according to country-specific guidelines. For example, Canada, Mexico and the US employ cordon distances that are specific to individual materials (Anonymous, 2008) whereas UK emergency services use an initial cordon distance of 400 m (based on explosive ordnance safety distances).

When the extent and nature of a contaminant source has been ascertained, an inner cordon should be imposed which is generally 25–50 metre radius around the contaminant (Fig. 2). This inner area is then referred to as the “hot zone” or “red zone”, with the area between the hot zone and the outer cordon being termed the “warm zone” or “white zone”. The area outside the warm zone is referred to as the “cold zone” or “blue zone”.

Table 3
Outline of current UK initial emergency response procedure referred to as “step one, two, three plus”. STEP; Safety Triggers for Emergency Personnel. The basic response applies to casualties exhibiting the same signs/symptoms at the same location at the same time.

Step	Observation	Action
1	One casualty, no obvious cause	Proceed normally
2	Two casualties, no obvious cause	Approach with caution
3 Plus	Three or more casualties in close proximity with no obvious cause	Use caution and follow national response procedure(s) for mass casualty incident

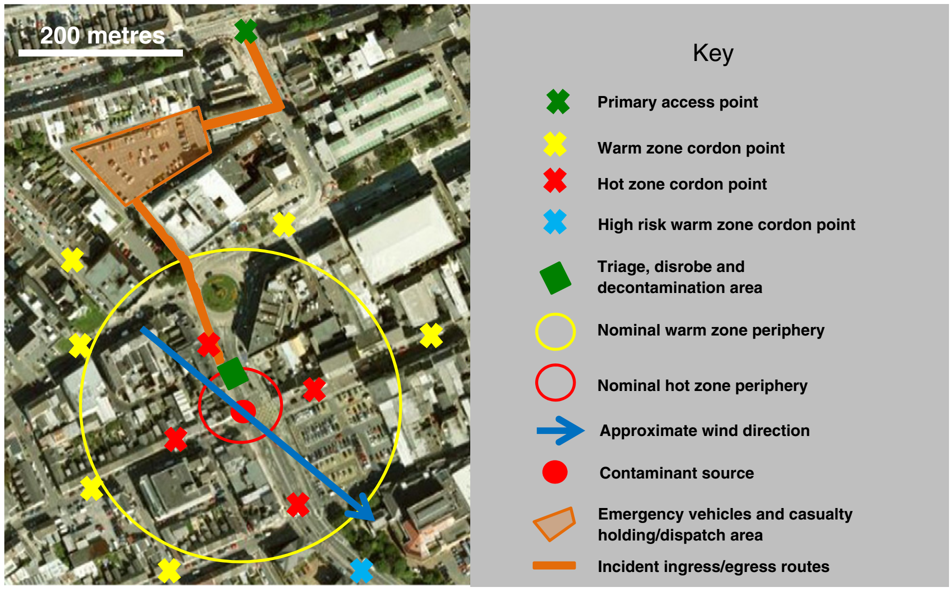

Fig. 2. Aerial view of an idealised incident response, indicating salient features such as position of cordon points, holding areas and main route of ingress/egress. Map reproduced from Google Maps ©2013 Google.

The hypothetical example provided (Fig. 2) indicates the salient geographical features of an incident response based on the release of a hazardous material at a road interchange in an urban environment:

- Responders in appropriate personal protective equipment (PPE) would control access to the hot zone.
- Further out from the incident, emergency personnel (in a lower level of PPE) would control access to the warm zone. Note that in this example, one of the warm zone cordon points (Fig. 2; bottom right) is considered to be "high risk" due to the prevailing wind direction and so higher level PPE may be required. In this particular example, access to the warm zone requires seven cordon teams: an environment with a more extensive network of public roads or footpaths would require more cordon teams. Thus, maintaining the warm zone perimeter could require extensive resourcing.
- The area reserved for emergency vehicles and casualty holding/dispatch area (Fig. 2: top left corner) can be considerably large. In this example, the designated area (car park) is within 400 m of the hot zone. A greater distance would normally be preferable but no such space may be available; this illustrates one of many practical challenges associated with mounting an effective incident response.

In addition to preventing more casualties, cordons can be employed to limit or prevent the egress of potentially contaminated individuals. The ability to control such movement of the public varies considerably: in many countries, such restrictions will have substantial legal implications. However, the use of a pre-planned public communication strategy may assist the task of isolating casualties through enhancing cooperation, reducing panic and promoting the effectiveness of countermeasures such as disrobing and decontamination (Carter et al., 2013b). Secure zoning can enhance the overall effectiveness of an incident response in several ways:

- Provides emergency responders with secure and unfettered access to the hot and warm zones.
- May limit the number of potentially contaminated casualties self-presenting at medical facilities. Many regions have emergency plans which involve the designation of specific hospitals for receiving contaminated individuals and so have appropriate decontamination, treatment and holding facilities along with specific procedures for securing staff and infrastructure. Unexpected attendance of casualties at inappropriately equipped medical facilities may cause extensive disruption to routine health services.
- A reduction in the unintentional spread of contamination (by people or vehicles) outside the hot zone. In addition to the attendant health benefits, containment will enhance the effectiveness and reduce the cost of post-incident environmental decontamination.

A practical disadvantage of zone enforcement may arise from the time and physiological effort required to traverse the relatively long distances between the hot and cold zones (for example, see Fig. 2). When setting zone distances, consideration should be given to the physiological burden associated with wearing PPE, an effect which will be augmented when manually transferring non-ambulant casualties (Fig. 3).

4.4. Administration of medical countermeasures

The advanced clinical management of casualties has traditionally been performed after evacuation and decontamination from the hot zone. Clearly, such a delay could decrease the survivability of a hazardous material incident, especially for non-ambulant, high-priority patients. As such, several countries have developed a capability to allow highly trained medical responders to operate within contaminated environments. In the UK, the ambulance services can deploy a Hazardous Area Response Team (HART) or Special Operations Response Team (SORT) to perform potentially life-saving procedures such as endotracheal intubation, intra-osseous antidote administration and haemostatic interventions within a contaminated environment (Fig. 3).

4.5. Disrobing

The act of disrobing (removal of clothing) is a simple but highly effective method for removing external contaminants from casualties and should be implemented at the earliest opportunity during an incident response (Clarke et al., 2008). It is often stated that disrobing can remove 80–90% of contamination from an individual (Wolbarst et al., 2010), although there does not appear to be any scientific evidence for this claim in the available literature. It is conceivable that the figure of 80–90% is derived from the "rule of nines" (Knaysi et al., 1968) on the assumption that all areas of the body except the hands and face are covered in relatively impermeable clothing. Recent (unpublished) studies

Fig. 3. Members of a Hazardous Area Response Team (HART) in full personal protective equipment (gas tight suits with self-contained breathing apparatus) transferring a non-ambulant casualty from the hot zone of a chemical incident exercise. Working in full PPE places a significant physiological burden on responders and can limit time in the hot zone. However, the use of such highly trained medical response teams may substantially improve survival rates for high priority casualties. Picture reproduced with permission of the Department of Health (England, UK).

performed with mannequins (Chilcott, 2009) have indicated that the effectiveness of disrobing is dependent on the orientation of the exposure: approximately 50% of a contaminant can be removed by disrobing following a vertical (overhead) exposure, increasing to around 70% following a horizontal (face-on) exposure. Regardless of the precise quantity of contaminant removed, it is clear that disrobing is an effective and practical means of reducing exposure to hazardous materials providing some basic precautions are taken. For example, clothing should ideally be cut from the upper torso rather than pulled over the head to prevent spreading and/or inhalation of the contaminant.

For liquid contaminants, the effectiveness of disrobing rapidly decreases with time due to diffusion of contaminant through the fabric layers (Fig. 4). For a single layer of cotton clothing (such as a t-shirt or denim trousers), the amount of liquid contaminant (such as chemical warfare agents) that can be removed by disrobing decreases substantially during the first 30 min of exposure (Matar et al., 2010). Therefore, it is essential that disrobing be performed as soon as practically possible when exposure to a hazardous material is confirmed or reasonably suspected.

Obvious practical challenges associated with disrobing are maintaining the privacy of casualties and the availability of replacement garments. Specialist response vehicles in the UK carry large numbers of "disrobe packs" (Fig. 5), with smaller numbers on fire appliances (fire tenders). Where a disrobe provision is unavailable, alternatives such as clothing from a local retailer may be available. In extremis, blankets, foil sheets or opaque plastic bags (e.g. large bin liners) may offer a temporary re-robing capacity.

4.6. Decontamination

Decontamination can be defined as the process of removing hazardous material(s) both on or available to the external surfaces of the body in order to reduce local or systemic exposure to a contaminant and thus

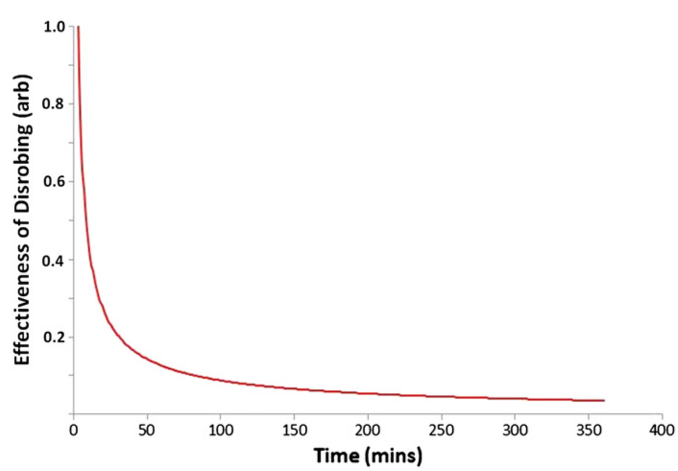

Fig. 4. Effectiveness of disrobing as a function of time post exposure following exposure to certain nerve agents. Effectiveness was calculated as the ratio of dermal absorption of the contaminants between control (unclothed) and clothed skin performed using an in vitro skin diffusion cell system (Matar et al., 2010).
Data reproduced with permission of the Department of Health (England, UK).

Fig. 5. Articles contained in the UK's mass casualty decontamination “disrobe pack” containing [1] high visibility poncho, [2] socks, [3] shoes, [4] particulate face mask, [5] gloves, [6] disinfectant wipe, [7] clothes cutter, [8] sanitary pad, [9] plastic bags, [10] identification bracelet, [11] waterproof instructions and [12] plastic tag. Each pack is individually vacuum-sealed to increase shelf life. The plastic bags, tags and identity bracelet carry the same, unique number.

minimise the risk of subsequent adverse health effects. In the US, mass casualty decontamination is commonly achieved using the “ladder pipe” method (Fig. 6) which showers individuals with large volumes of water under relatively low pressure (Lake et al., 2000). In contrast, the UK has a bespoke decontamination capability which uses heated water within a temporary, sheltered structure (Fig. 7).

Decontamination is generally performed in the warm zone following evacuation of casualties from the hot zone. However, a small number of countries (for example, Israel) have adopted an alternative approach whereby casualties are transported from the scene of an incident to medical centres with decontamination facilities (Anonymous, 2006). This obviates any delays inherent to assembling temporary decontamination structures at the scene of an incident. In theory, hospital and on-scene decontamination have relative merits and disadvantages, although there is little practical experience upon which to base an evidence-based comparison.

It is important to consider decontamination as part of a single procedure which extends the initial process of disrobing rather than a separate stage of casualty management. The need to remove clothing prior to decontamination is based on several principles:

i. Contaminated clothing may present a hazard to casualties and emergency responders.
ii. The presence of grossly contaminated clothing may increase the toxicity of effluent arising from aqueous decontamination procedures.
iii. Decontamination may be rendered ineffective by the presence of clothing.
iv. Water-based decontamination may assist the transfer of contaminants through clothing and could increase skin surface spreading.

As with disrobing, time is a critical factor in the effectiveness of decontamination and so should be performed as soon as reasonably possible.

Decontamination can be broadly categorised as “wet” or “dry”. Wet, or aqueous-based decontamination, relies on the use of water (optionally containing detergents or other excipients such as bleach) to wash and rinse potentially contaminated areas of the hair and skin. The main advantage of wet decontamination is that the raw material (water) is ubiquitous in developed countries and so access to municipal or domestic supplies can generally be assured during an incident. However, wet decontamination has several challenges:

- Uncontrolled waste may increase the mobility of the contaminant within the environment.
- Viscous substances may be difficult to remove.
- Lipophilic (oily) substances may have limited dissolution rates and so detergents may be required. An (unpublished) study has indicated that aqueous detergent solutions can remove ~40% more skin contamination than water alone.

Fig. 6. Demonstration of the ladder pipe system (LPS) for mass casualty decontamination. Individuals are directed to walk through a high volume water mist generated by overhead and side fogging nozzles from two adjacent fire tenders.
Reproduced with permission of the US Department of Health and Human Services Biomedical Advanced Research and Development Authority (2013).

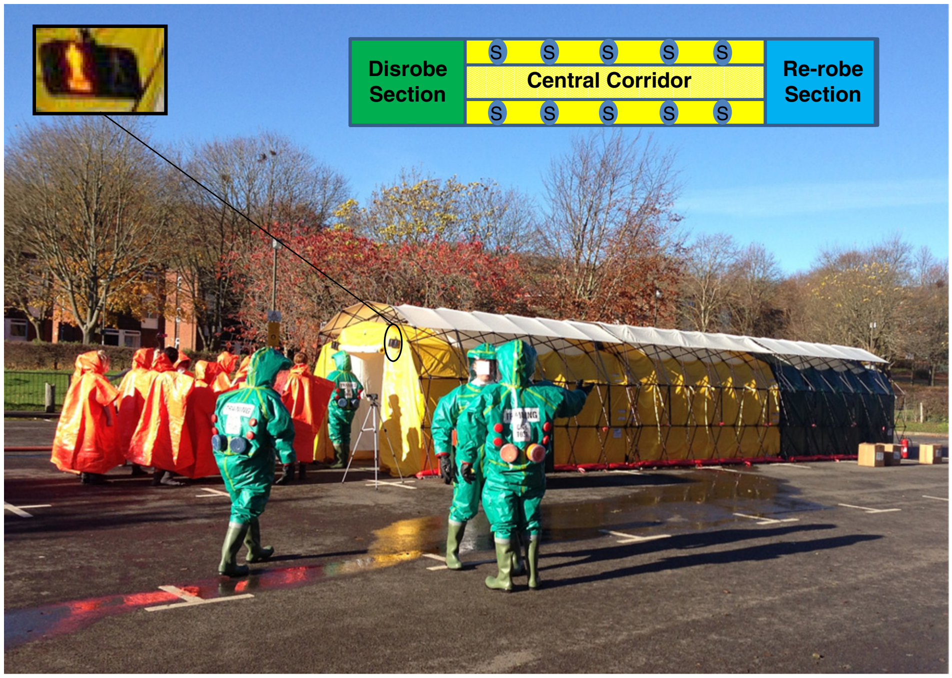

Fig. 7. Mass casualty decontamination unit (“MD1”) deployed by UK specialist responders. Photograph acquired during an exercise and shows a group of 10 individuals in high visibility ponchos (Fig. 5) waiting to enter disrobe area in accordance with a “traffic light” system (inset, top left). Schematic of unit (inset, top right) indicates position of disrobe area, two side corridors (each with five shower areas [“S”] for decontamination of ambulant casualties) and a central corridor (used by responders to observe or instruct individuals) which can be adapted for processing non-ambulant casualties. Air heaters and boiler for shower water are at the rear of the tent and so not shown in this image.
Reproduced with permission of Public Health England ©2013.

- Showering of individuals may potentially lead to hypothermia where heated water or shelter is unavailable.
- Some studies have indicated that water may enhance the dermal absorption of certain contaminants (Moody and Maibach, 2006). This effect can be markedly reduced by limiting the duration of wet decontamination to less than 90 s.

Bleach (hypochlorite) has been suggested as a means of neutralising chemical contaminants and animal studies have confirmed some degree of effectiveness (Bjarnason et al., 2008). However, the threshold dose of hypochlorite for eye irritation (0.5%) is of questionable value for the rapid and complete neutralisation of chemicals on the skin surface.

A recent (unpublished) study has produced evidence-based recommendations for optimising aqueous decontamination (Chilcott, 2009). The resulting “ORCHIDS Protocol” (Table 4) is currently being implemented by the UK emergency services.

Many existing showering protocols require individuals to stand or walk through the decontamination area without making any effort to clean themselves. However, physical cleaning of the skin surface (for example, through the use of a flannel or cloth) can improve the effectiveness of decontamination by *ca.* 20% (Amlot et al., 2010). Such an intervention represents a simple yet cost effective means of substantially improving the efficacy of mass casualty decontamination. Where self-cleaning is not part of a decontamination procedure, the active stage of decontamination is likely to occur *after* showering when the skin and hair are being dried (for example, with a towel). Towel drying can remove up to 30% of a skin contaminant (unpublished data) and so is an integral part of the decontamination process. With this in mind, care should be taken in the subsequent handling and disposal of materials that have been used to dry individuals after decontamination showering.

Table 4
Summary of conditions for optimisation of aqueous (shower based) decontamination according to the “ORCHIDS Protocol”.

Parameter	Optimal condition	Reference
Shower water temperature	35 °C	–
Shower duration	60–90 s	Larner et al. (2010)
Detergent	0.5% (v/v) Argos™ or FloraFree™	Jones et al. (2010)
Washing aid	Cotton flannel (facecloth)	Amlot et al. (2010)

A number of commercial suppliers offer various designs of decontamination shower units. These include small (single user) stands, rapid-deployment (multiple user) tents and permanent, hard-walled installations. More advanced systems provide control of the pressure, temperature and excipient concentration (e.g. detergent) of the shower water and have separate, heated areas for disrobing, showering and re-robing. In some cases, the rate at which individuals pass through each section may be automated using illuminated signs (e.g. “traffic lights”; Fig. 7). Controlling the passage of casualties through a decontamination facility is important in order to ensure that each individual has the correct shower time and that any rate limiting steps (for example, re-robing) can be achieved without causing disruption to the overall flow of casualties through the unit.

One of the more obvious disadvantages of deploying a bespoke decontamination unit to the scene of an incident is timing. As discussed earlier, disrobing and decontamination are time-critical: Delivering a decontamination unit and then achieving operational readiness will inevitably incur a delay. Therefore, interim forms of decontamination may be required during the early phase of an incident response.

Interim (or emergency) decontamination can be achieved through the use of water delivered from fire hoses, municipal showers or by simply using a bucket of water and a sponge. Potential problems associated with such wet methods include hypothermia, availability of resources, loss of contaminated effluence to the environment and spreading of the contaminant over previously non-contaminated areas of skin. Thus, dry decontamination may be preferable.

In general, the process of dry decontamination utilises the absorbent properties of powders or fabrics to passively remove contaminants from the skin surface and is particularly effective for liquid contaminants

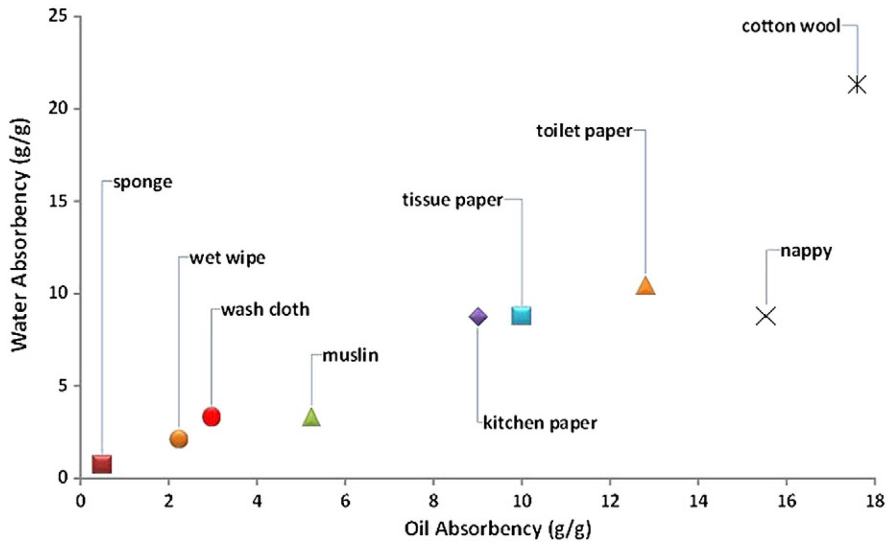

Fig. 8. Absorbency (gramme of water or oil absorbed per gramme of test product) of a range of common domestic materials. Data provided for illustrative purposes only and does not represent an endorsement of any particular type of product.

(Chilcott, 2007). In some regions of France, the formal process of wet (showering) decontamination is often preceded by dry decontamination of casualties using Fullers' earth ('Gant Poudre'). This can achieve a more rapid, initial decontamination and may assist in reducing gross contamination prior to showering (Josse, 2010).

Many common items that are considered "absorbent" demonstrate some degree of affinity for both water and oil-based substances (Fig. 8). Thus, a practical approach to interim decontamination may be achieved using any available absorbent material such as paper (tissue, towel, kitchen, etc.) or nappies (diapers). However, there is currently no available evidence to confirm the effectiveness of such products against toxic materials and extreme caution should be exercised when handling or disposing of such items after use as a decontaminant.

5. Subsequent actions

Where contamination has been confirmed, transfer of ambulant casualties from the warm to cold zone (casualty holding area; Fig. 2) will normally occur only after disrobe and decontamination have been completed. In contrast, non-ambulant casualties will generally be transferred directly to a nominated medical facility for further treatment. In such circumstances, medical staff will need to be guided by institute-specific procedures in terms of the need for further decontamination and use of PPE.

The casualty holding area should provide a dry and comfortable environment during which further triage and medical treatment may be performed. In addition, the holding area can be used by the emergency services to take personal details and record witness statements. The acquisition of personal details can provide relevant information for future health surveillance and so may be essential following exposure to hazardous materials which may have long-term health effects. In addition, there may be a delay in returning personal belongings (removed during the disrobing process) to individuals, especially if they require decontamination. Thus, recording contact details will facilitate the process of reuniting an individual with their personal items.

6. Conclusions

Careful planning and regular exercising of capabilities is the key to implementing an effective response following the release of hazardous materials, although ad hoc changes may be inevitable. The critical actions are evacuation, immediately followed by disrobe and decontamination. Following transfer to a safe holding area, each casualty's personal details should be recorded to facilitate a health surveillance programme, should it become apparent that the hazardous material has long-term adverse health effects.

Acknowledgements

The unpublished work cited in the text mainly refers to project ORCHIDS which was co-founded by the Department of Health (England), European Union (Executive Agency for Health and Consumers) and UK Home Office. Further details are available on the project website: www.orchidsproject.eu. The work was co-ordinated by the Health Protection Agency (now Public Health England) and was performed by members of the CBRN and Chemical Toxicology Team (D.R. Jones, J. Larner and H. Matar) and Behavioural Sciences Research Team (Dr R. Amlôt, H. Carter and L Riddle) with assistance from Dr J. Wakefield. Data on the absorbency of domestic products was acquired by Dr Nicholas Kassouf and Mr Elliot Thomas. The author would also like to thank members of the Los Angles Fire Department for demonstrating the ladder pipe system of decontamination (Fig. 6) as part of a project sponsored by the Biomedical Advanced Research Development Authority (BARDA).

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