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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.

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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

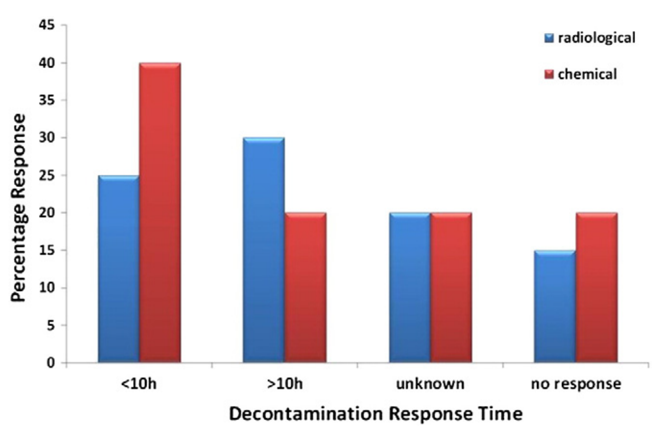

Fig. 1. Decontamination response time results from a survey of EU Member States Countries performed as part of the "mass casualties and healthcare following the release of toxic chemicals or radioactive material" project (Baker, 2010; Meineke et al., 2010).

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