Doctors Christina Baxter, Michael Logan, Sharyn Gaskin and Dino Pisaniello take an evidence-based approach to the mass decontamination paradigm

Paradigm shift

Introduction

Accidental or intentional releases of toxic gases or vapours are the most common type of hazardous material (hazmat) incidents causing human injuries. Typically, these releases are associated with industrial accidents (eg a chlorine gas release after a train derailment in South Carolina) and terrorism-related events (eg the Tokyo subway nerve agent sarin attack). Historically, deliberate releases of hazardous materials and chemical agents have been sparse. Nonetheless, in the last few years, deliberate releases of chlorine, mustard agent, and sarin in Iraq and Syria have occurred illustrating continuing nation and terrorist group interest. This ongoing interest poses significant challenges to emergency responders globally to ensure they are prepared to manage the consequences of a release particularly of gases and vapours.

Hazardous materials have significant effects on public health and impose significant demands on hazmat response resources. During and following hazmat incidents, four main groups of people are affected. They are:

- exposed and deceased.
- exposed and symptomatic.
- exposed and asymptomatic.
- unexposed and asymptomatic.

Those exhibiting symptoms, who are acutely effected by inhalation exposure are the most clearly recognised, and can be triaged and evacuated to hospital or treated at the scene. There may be a small subset of the unexposed and asymptomatic group which exhibit symptoms from asthma or other underlying disorders. These people are also often triaged and either evacuated to a hospital or treated at the scene. However, the onsite management of exposed, but asymptomatic individuals is problematic as it may be numerically large and potentially resource-intensive. The last group also known as the worried well, may self-present to first responders at the scene, or at nearby hospitals or medical facilities. They impose further demands on valuable resources and add to the potential delay in identifying and treating those needing lifesaving medical treatment.

Globally, the default approach is to decontaminate the skin of all exposed persons regardless of whether or no they exhibit symptoms, using field portable shower systems. Jurisdictions across the world have invested hundreds of millions of dollars establishing and extending their field deployable mass decontamination resources.

Nonetheless, a significant incident will likely rapidly overwhelm the available field deployable hazmat mass decontamination capacity.

Studies have reported[1-3] on refining the mass decontamination process, but have not asked the question: Do affected persons need decontamination after exposure to gases and vapours?

Reducing the number of people to be decontaminated has a huge effect on emergency responder resources. For example, reducing the number of people requiring decontamination by 80% reduces the emergency responder resource demand by 63%. These precious resources can then be applied to the areas of greatest need at the incident.

Can we find a way to objectively reduce mass decontamination of exposed persons without comprising their health?

This article considers this question and applies recent research into the nature of the interaction of gases/vapours with the skin during mass decontamination operations.

The skin plays an important role preventing the ingress of chemicals, particularly gases or vapours, into the body. However, in a hazmat context there has been limited evidence describing the extent of the risk that skin contact and absorption of gases or vapours poses. A variety of factors affect the skin's (dermal) absorption of chemicals, particularly gases and vapours, including skin thickness, skin integrity (damage/disease), clothing, temperature and properties of the chemical itself. There also remain many questions about the role clothing plays, such as whether it initially acts as a buffer to prevent skin contact with the gas or vapour, but there appear to be no systematic studies assessing whether street clothing provides any protection.

Many nations have developed lists of

Figure 1.
Mass decontamination trailers used by Fire Services at an incident ©M Logan

Paradigm shift

chemicals of concern, to help responders and their communities prevent misuse and prepare to manage the consequences of a deliberate release of hazardous materials. These chemicals include chlorine, phosphine, and ammonia. The chemical lists have been used as a basis for prioritising research into the interactions of gases with skin.

Over the past few years a collaborative effort between the US and Australian governments has been in progress to determine the nature of the interaction of gases/vapours and the skin. These chemicals have been sorted into three groups. They are:

- reactive gases such as chlorine and hydrogen chloride.
- biochemical degradation gases like hydrogen cyanide and hydrogen sulphide.
- fumigant gases like phosphine and methyl bromide.

Gaskin et al[1-4] used freshly excised human skin and also looked at the effect clothing has on the interaction between gases and the skin in these studies. Their investigations focussed on gas/vapour concentrations and exposure times that were operationally relevant. For example, concentrations above the lowest lethal concentration (LC-lo) of the gas or vapour were not operationally relevant since at this concentration exposure of the affected person was likely to be immediately fatal. Instead, concentrations below this value were examined such as the immediately dangerous to life or health (IDLH) and workplace exposure standards (WES) or their equivalents.

Despite the inhalation toxicity of these gases, the results obtained by Gaskin et al[4-7] challenge traditional notions about skin toxicity at the concentrations of interest and exposure times in the context of a hazmat incident. Gaskin et al also showed simple measures such as ventilation were often viable approaches to decontaminating exposed persons. Clothing also played a role, often acting initially as a barrier.

What do the results say, and how can we take advantage of them to challenge and improve our

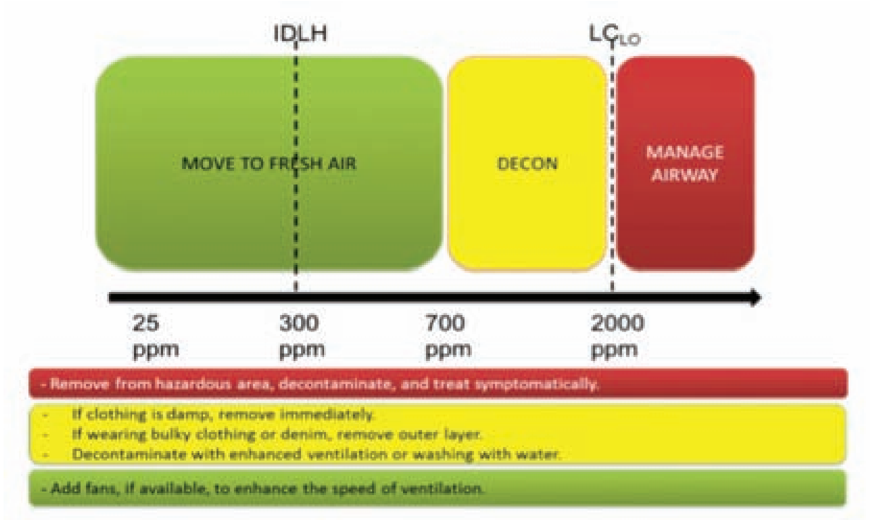

Figure 2.
Example of a risk-based approach for skin decontamination decision making for ammonia exposures

decontamination approaches?
Let's start at the lowest concentration of concern, the WES or similar exposure values, eg the US permissible exposure limit (PEL). This value is typically applied to define the warm zone boundary at a hazmat incident. For all gases investigated, there was no effect on the skin at this concentration in a hazmat context. This also holds true at different temperatures and humidity. No shower based decontamination is required, and moving the exposed person to fresh air is sufficient.

At IDLH level there was no effect on the skin for all gases investigated in a hazmat context. This also applied at different temperatures and humidity. As with exposures at the WES, no shower based decontamination was required and moving the exposed person to fresh air was appropriate. The IDLH concentration is important since it is typically applied as boundary defining the hot zone and the value at which self contained breathing apparatus must be donned to prevent inhalation of the gas or vapour.

At concentrations above the IDLH, the story about interaction of the gases on the skin begins to change for some of the chemicals investigated by Gaskin et al. Nonetheless, many gases had no effect in a hazmat context and they included: hydrogen cyanide, hydrogen sulphide, sulphuryl difluoride, methyl bromide, hydrogen chloride, and sulphur dioxide. There are no interactions even when the humidity and temperature change.
Chlorine, ammonia, nitrogen dioxide, and phosphine did interact with the skin at concentrations above the ILDH. Of these gases, chlorine and nitrogen dioxide exhibited the greatest absorption at the LC-lo, whereas the skin absorption of phosphine and ammonia was negligible at the LC-lo. For chlorine, longer exposure times and humidity also assisted skin absorption Street clothing also played a part, the role being dependent on the chemical. For example clothing initially acted as a barrier for ammonia absorption, but acted as a reservoir if the clothing was wet. In general, removing the outer clothing greatly assisted the removal of any gases or vapours trapped in the clothing. Using fans or even the wind further aids decontamination, speeding up the removal of any gas trapped in clothing.

The overall results can be summarised into risk based operational guidance to support decontamination decision making at an incident. An example of how the guidance can be presented is shown below. It is separated into three key zones, showing where:

- no decontamination is required other than moving the person to fresh air.
- decontamination should be

considered against organisation policies and a precautionary approach adopted.

- decontamination should occur.

Further guidance is provided to manage any impact from the person's clothing. If someone has damaged skin or a skin disease then decontamination should always be considered. This risk-based operational guidance to support decontamination decision making can be extended and applied to all chemicals that may be released. It can also be applied to contact with liquids and solids as a result of understanding the nature of their interactions with the skin.

Those identified as having relatively low exposures, can be removed to fresh air for medical assessment without significant risk of suffering adverse effects or any risk from off gassing to emergency medical responders on site or at a medical facility such as a hospital. Others, identified as having high exposure and thus needing expert support may be prioritised for decontamination at the scene. To make decisions during this triage phase, emergency responders must have information regarding the likely levels of exposure, the potential for dermal contact and uptake, and the likely effects arising from that exposure.

The knowledge gained about the interaction of the gases/vapours and the skin combined with the incident factors such as temperature and clothing has been integrated into operational decision making tools such as the emergency response decision support system (ERDSS). This CBRN decision support software can be obtained from www.chemicalcompanion.org.

Summary

This new and evolving understanding of the nature of the interaction of gases, skin, and clothing in operationally relevant timelines provides a basis for rational decision making by first responders dealing with potential casualties in the event of a chemical release. Overall, these results challenge the current dogma requiring mass personal decontamination by strip and shower for all exposures. It has significant and positive impacts on the use of resources at an incident and which affected persons the emergency services should focus on.

In practice, rather than use a one size fits all mass decontamination approach to all potentially contaminated individuals during a hazmat incident, the emergency services can triage using objective exposure criteria. This will significantly reduce the number of people undergoing mass decontamination by excluding lightly exposed individuals. Consequently, the emergency services can focus their mass decontamination efforts on those truly needing decontamination before medical treatment.

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First responders need to move away from the 'one size fits all' mentality ©CBRNe World

References

1. Chilcott R, Amlot R. (2015) Primary Response Incident Scene Management (PRISM). Guidance for chemical incidents: Volume 1: Strategic guidance for mass casualty disrobe and decontamination.
2. Chilcott R, Amlot R. (2015) Primary Response Incident Scene Management (PRISM). Guidance for chemical incidents: Volume 2: Tactical guidance for mass casualty disrobe and decontamination.
3. Chilcott R, Amlot R. (2015) Primary Response Incident Scene Management (PRISM). Guidance for chemical incidents: Volume 3: Operational guidance for mass casualty disrobe and decontamination.
4. Gaskin S, Pisaniello D, Edwards J, Bromwich D, Reed S, Logan M, Baxter C. (2013) Application of skin contamination studies of ammonia gas for management of hazardous material incidents. Journal of Hazardous Materials, 252-235: 338-346.
5. Gaskin S, Pisaniello D, Edwards J, Bromwich D, Reed S, Logan M, Baxter C. (2013) Chlorine and hydrogen cyanide gas interactions with human skin: In vitro studies to inform decontamination in hazmat incidents. Journal of Hazardous Materials, 262: 759-65.
6. Gaskin S, Heath L., Pisaniello D, Evans R, Edwards J, Logan M, Baxter C. (2017) Hydrogen sulphide and phosphine interactions with human skin in vitro: Application to hazardous material incident decision making for skin decontamination. Toxicology and Industrial Health, 33(4):289-296.
7. Gaskin S, Heath L, Pisaniello D, Edwards J, Logan M, Baxter C. (2017) Dermal absorption of fumigant gases during hazmat incident exposure scenarios – methyl bromide, sulphuryl fluoride and chloropicrin. Toxicology and Industrial Health, 33(7): 547-554.