APPROACHES THAT DECONTAMINATION OF CHEMICAL WAR FAIR AGENTS AND TOXICAL INDUSTRIAL CHEMICALS

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Abstract: *Adequate and timely protection of the people and the infrastructure necessary increase efficiency in liquidation of the consequences of chemical, radiological and biological agents. CBRN decontamination teams are using decontamination technique to minimize exposure to hazardous agents and limit the spread of contamination. The disposables decontamination means and methods are very divers, and an evaluation of the most appropriate aspects often encountered in the real cases could determine the adequate organization approach to be used.*

Keywords: chemical, radiological and biological agents, decontamination

1. Introduction

The threat of exposure of the civilian population to nuclear, biological, and chemical agents, which has traditionally been considered a military issue, has increased due to the potential causes from direct military attacks, stolen weapons of mass destruction (WMDs), acts of terrorism, and industrial accidents and disasters. Based on mass casualty effects, the release of such CBRN agents might create thousands of casualties, thereby overwhelming local health and medical resources. The specificity of the likely CBRN situation that may be created after terrorist actions and new approaches to unclear identification, protection of endangered entities and eradication of the latter. Consideration should be given to reconsidering the political, military and civilian approach. For that reason, CBRN protection should be seen as a comprehensive political, military and civil approach based on the main pillars of prevention, protection and rehabilitation. [11, 12, 13, 14].

The proliferation of WMD and the associated threat of terrorism are among the most serious challenges for the international community in post-Cold War security. An important challenge for NATO is to find its place in international efforts against the proliferation of these substances and materials.

2. Protective zones after chemical incident

Response areas as defined in [2] and schematically shown in Figure 1 below are important for determining the response roles / places and PPE requirements for release events. Note that the dimensions and location of these zones may change over the course of an event.

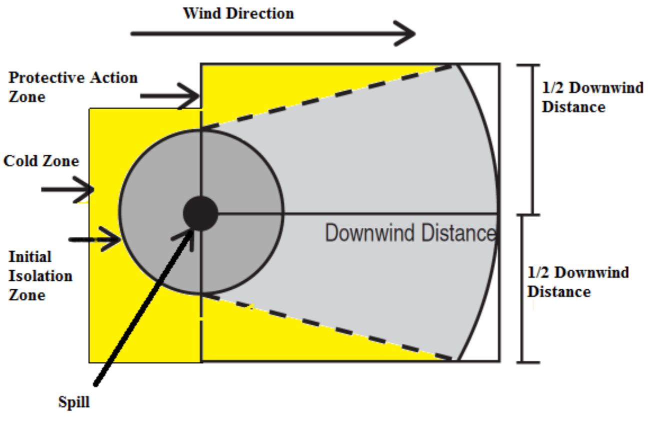

Fig. 1 *Protective distance after chemical incident. [1, 2]*

The initial isolation zone (hot zone) is the innermost of three main areas of chemical spill. It is the area in the immediate vicinity of a release, the release occurs at the center of this zone and it contaminant concentration is considered sufficient to cause death or injury to unprotected personnel or responders wearing inappropriate protective clothes and gas masks. All people entering the hot zone must wear prescribed levels of protection MOPP 4, and they must follow the procedures established to enter, work in the area, and exit the zone in a short time. [1, 2].

The warm zone is located upwind and outside the hot (initial isolation) zone and protective action zone, between the hot zone and the cold zone. The inner perimeter marks the outside edge of this zone and is considered the initial control zone. This is the area that provides a transition between contaminated areas and the uncontaminated areas. The warm zone provides a buffer to further reduce the probability of the cold zone becoming contaminated or being affected by other existing hazards. Decontamination of personnel and equipment takes place in a portion (decontamination corridor) of the warm zone (fig. 2). The main decontamination facility/corridor is located at the exit point of the warm zone. Responders in the warm zone must have property protective clothes and gas masks appropriate to the tasks they will undertake.

The protective action zone is located downwind from the chemical release. Individuals in this area may be evacuated, sheltered in place, or supplied with protective equipment. This zone could be several square kilometers in size, regardless of whether the release takes place indoors or outdoors. The protective action zone can evolve over time.

The cold zone (or clean zone) is the outermost part of the release or incident site, and is a designated non-contaminated or clean area. The outer perimeter marks the outside edge of this zone, surrounding the incident scene. Support equipment and vehicles and main military formations such as command staff are located in the cold zone and traffic is restricted to authorized response personnel. MOPP 4 level is not required in this zone because exposure levels are below levels causing effects. Potentially contaminated personnel, clothing, equipment, and samples are not permitted in this zone, but are left in the warm zone until they are decontaminated or made safe for transport. The boundary between the cold and warm zone is defined based on the extent of contamination spread; there may be contamination within the warm zone but none in the cold zone.

Decontamination focuses on remediation of various locations and equipment with which chemical agens have come into contact and avoid spread and contamination.

The goal of decontamination is to reduce the overall hazard to acceptable levels as rapidly and expediently as possible. Minimizing contamination and the spread of contamination is primarily achieved by avoiding direct contact with liquid, solid, vapour or aerosolized contaminant. Gross decontamination involves the removal of as much contaminant as early as it is safe to do. The spread of contaminant is controlled by ensuring that the decontamination corridor is capable of containing the amount of expected contaminant, the flow of the run-off (if present) is directed towards the hot zone, and the movement along the decontamination line is closely regulated. There are many different ways of reducing contamination and the end goal is to achieve a safe level of contaminant.

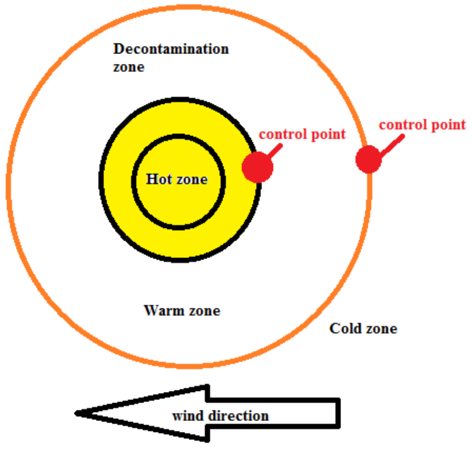

Fig. 2: *Decontamination area in chemical incident (adapted from Fig. 1).*

Decontamination can be defined, as a method essentially involving the conversion of toxic chemicals into harmless products by degradation. Decontamination is based on one or more of the following principles:

- to destroy chemical agents by chemically modifying these(destruction);
- to physically remove chemical agents by absorption, washing or evapouration;
- to physically screen-off the chemical agents so that these cause no damage.

Decontamination measures for PPE may include/involve absorbents, adsorbents, vacuuming, evaporation, chemical degradation, dilution, wash-down or simply clothing removal. These measures will vary according to the contaminant, the phase of the activity and the item that is contaminated. During decontamination, PPE remains in place until deemed safe to be removed.

2. Decontamination approaches and effectiveness.

Decontamination approaches of chemical warfare agents and TIC (toxic industrial chemicals) is a complex process and can beconsidered in different ways. From methodological point of view, there are three basic methods of decontamination: mechanical decontamination, physical decontamination and chemical decontamination.

There are several basic approaches to hazard decontamination that can themselves be achieved by a variety of means

- Placing a barrier around the contaminant to render it unable to cause harm;
- Removing the contaminant without deactivating it, sometimes by dilution into some other medium such as water or air (a physical process), or by absorbing/adsorbing onto something else, meaning that it is either relocated and further treated by other means, or diluted sufficiently for safety; or, lastly and preferably,
- Breaking down the contaminant, by various means, most commonly chemical (e.g., bleach).

In the case of creating a barrier, the responder should not normally be in direct contact with the original contaminant, and therefore any PPE selection is based on attenuating whatever lesser hazard there is remote from the initial contaminant (such as off-gassing).

In the case of removal, the responder could contact the agent during the removal process, for example by being splashed by contaminated water. Hence, PPE must act as a barrier against both the contaminant and any removal medium or process.

Lastly, in the case of breaking down the contaminant, chemical means in particular can be quite dangerous on both humans and their PPE, so PPE must be chosen to resist both the agent's action as well as that of the chemical decontaminant used.

Appropriate process is of course extremely important in minimizing the possibility of excessive spread and transfer of contamination during decontamination. Once decontamination of the contaminated item (whether it be the environment, equipment, or an individual) is complete, the remaining consideration is how to safely doff PPE that may still have some contamination on it. Therefore PPE must always be chosen with safe doffing in mind.

Wet and dry decontamination approaches are both employed, with various advantages and disadvantages. Wet decontamination usually implies the use of sufficient quantities of (generally) water-based decontamination solutions that dilute and remove contaminants. If it possible the personnel can use a surfactants and hot water to remove a lot of chemical agents until full decontamination. Dry decontamination implies the use of totally dry or minimally damp approaches such as spraying with fine aerosols or vapors, wiping or vacuuming. An approach like misting with bleach or application of reactive skin decontamination solutions is closer to dry decontamination because a large excess of decontamination solution is not used. As a result of their potential for penetration of the equipment, dry and wet approaches impose different requirements on PPE. [6, 7, 8, 9]

In Fig. 3 shows the metology that can be applied when selecting the decontamination method.

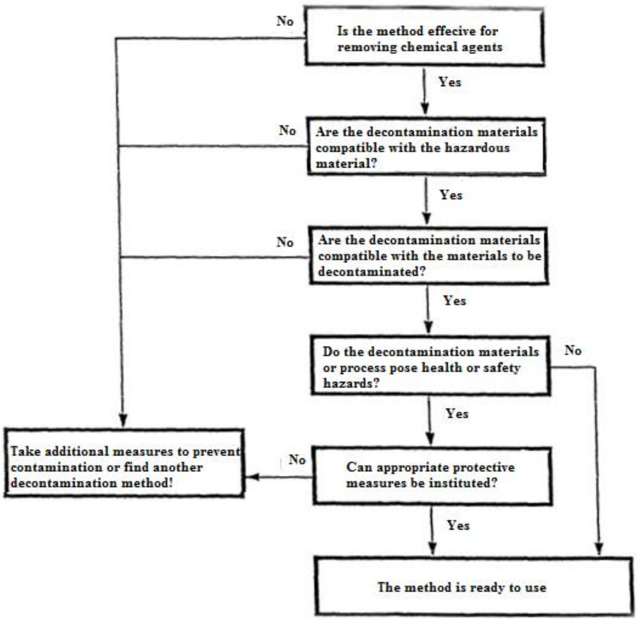

Fig. 3: *Methodology to choose an decontamination method.*

For chemical agents, evaporation is assumed to begin after the conclusion of the dissemination and deposition processes and continues as victims travel to and arrive at the medical facility. Evaporation prior to decontamination will limit hazards created by extremely volatile, quickly evaporating materials such as phosgene. Fedele et al. [3] derived characteristic time constants for the evaporation of CWAs. The time constant, τ, is the time for approximately 63% of the existing amount of material to leave the surface. This constant is defined in Equation (1):

$$\tau = \frac{m_0}{C_{vol} V_{etr}}, \quad (1)$$

Where are: C_{vol} - is the volatility of the liquid, d.m^{-3}; m_0 is the initial mass per unit area, g.m^{-2}. V_{etr} is an empirically determined evaporation transfer rate, m.min^{-1}.

The effectiveness of a decontamination procedure can be expressed as the decontamination factor (DF). It is the ratio of contamination concentration on material before decontamination to the residual contamination concentration on the material after decontamination as given in Equation (2):

$$DF = \frac{C}{R}, \tag{2}$$

Where are: C - is concentration of the contaminant before decontamination, g/m^3; R is residual concentration after decontamination, g/m^3.

A decontamination process that removes material will result in a DF greater than 1. The percentage of contamination removed from the surface can be given by Percent contamination removed (Equation (3)):

$$\%remuved = \left(1 - \frac{1}{DF}\right), \tag{3}$$

Such analysis is useful in the laboratory, but in practice the efficacy of decontamination on-site is rarely validated in any meaningful way, even in rehearsal. The common question of "how clean is clean?" [4,5] for site remediation holds equally for personnel decontamination activities—how does the responder know when the PPE is clean enough or the air in the decontamination line is clean enough to remove PPE? How does the responder know whether further skin decontamination is needed, and when it has been adequate?

In theory, knowledge of the agent and appropriate exposure limits combined with near real-time surface and air sampling by appropriate detectors would be required to answer these questions at the time of the incident. [10, 12]

In fact, there are little published data that directly support the question of how much contamination can be removed from a person after chemical exposure by removing the person's clothing despite the frequent claims of values such as 80-90% [4]. This information is relevant to PPE decontamination as well. The results are likely to vary depending on the surface being decontaminated (PPE being worn), the specific hazard agent and its physical state (i.e., solid, liquid, vapor or gas).

4. Conclusion

The choice of a suitable area for decontamination should take into account the main features: water sources, terrain, meteorological influences, but also an accurate assessment according to the zones that are determined after a factual reconnaissance. The effectiveness of field decontamination is difficult to determine in a mathematical way, it is necessary to carry out CBRN intelligence.

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