CHIMIA **2004**, *58*, No. 1/2

Chimia 58 (2004) 33–36

ISSN 0009–4293

Decontamination After Chemical Incidents

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Abstract: Incidents with release of chemicals are insidious. The HazMat team has not only to overcome the immediate consequences of a spill but also the decontamination of casualties, fire service personnel and equipment. By following the zone concept and correct procedures, emergency services personnel can minimise the risk of contamination. Training of proper decontamination principles is a demanding task. Proven decontamination procedures are described in detail and some case studies are presented.

Keywords: Decontamination procedures · Hazardous materials incident · Rescue chain · Training of HazMat teams · Zone concept

1. Introduction

Decontamination of protective clothing and equipment is, in the majority of cases, the minimum action necessary following deployment of a fire service or a HazMat unit in response to a release of hazardous substances in solid, liquid or gas form.

The following article is concerned only with chemical contamination and does not contain any information about decontamination following incidents involving radioactive or biological materials.

It should be stressed here that preventing contamination is always easier, less time-consuming and less hazardous than carrying out decontamination after an incident. By following the correct procedures, emergency services personnel can minimise the risk of contamination and hence the need for subsequent decontamination.

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2. Hazard Potential

Chemicals can be released as solids, liquids or gases during an incident. Other things being equal, the hazard potential of a material is a function of its physical state, with gases posing a greater hazard than solids, whereas the risk of contamination decreases with increasing distance from the incident (Table 1).

Table 1. Hazard potential in terms of physical state

	Solid	Liquid	Gas
Casualties	High	High	High
Emergency services personnel	Low	High	High
Population	Low	Medium	High
Environment	Low	Medium	Low

In addition to the released chemicals themselves, contaminated extinguishing water and, not least, waste liquids from the cleaning of casualties and equipment pose a contamination risk.

Humans and animals can absorb hazardous substances through the skin, eyes, and respiratory and digestive tracts, resulting in poisoning and/or chemical burns.

Substances with a latency period are particularly insidious, as the onset of harmful effects can be delayed by hours or even days. The inhalation of lung irritants that have a latent effect can lead, days later, to a fatal pulmonary oedema if the proper corrective action is not taken quickly enough (*e.g.* the administration of dexamethasone spray) (Table 2).

If fire service vehicles and equipment become contaminated, there is a risk that this contamination will be transferred to the fire station and pose a further hazard to personnel. A range of substances can cause serious corrosion problems if no corrective measures are taken. Cases have been reported in which the breathing apparatus used at an incident had to be replaced.

3. The Zone Concept

Swiss emergency services personnel are taught that the first unit to arrive at the scene of an incident should cordon off 'zone 1' (also known as the hot zone) after taking any immediate action necessary. Taking the wind direction into account, the

Table 2. Types of lung irritants

Substance	Effect
Ammonia	immediate
Hydrogen chloride	immediate
Chlorine	latent
Ozone	latent
Sulfur dioxide	latent
Nitrous gases	latent

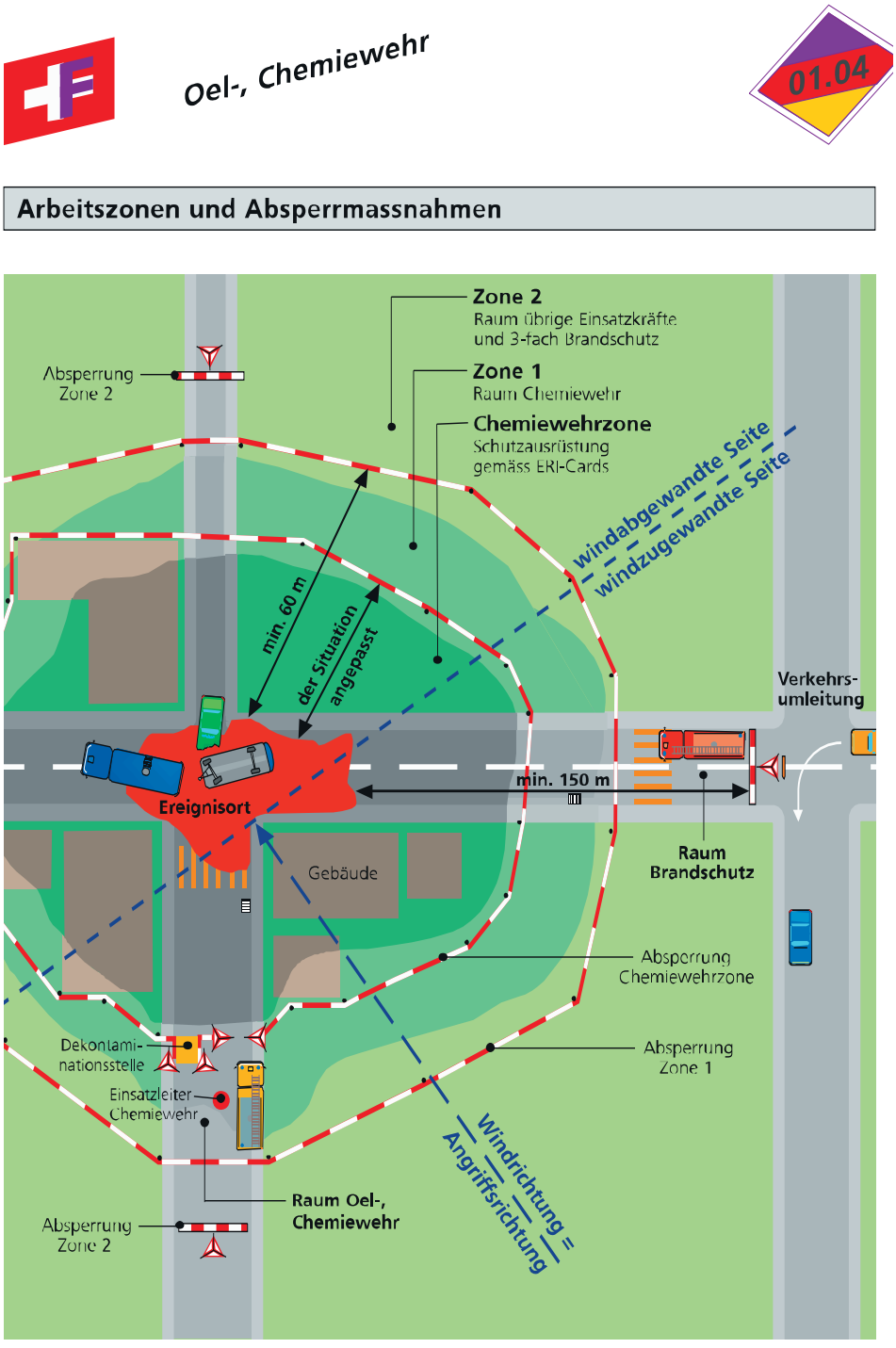

Fig. 1. Zone concept and cordon off measures as defined in Swiss file Oil, Chemical and Radiation Defence. For details see section 3.

perimeter of this zone should be established at a distance of 60–100 m from the incident. To protect any nearby residents and ensure that emergency services have enough room to carry out operations, 'zone 2' (also known as the warm zone) should then be set up with boundaries extending 150–500 m from the incident. This zone is not usually cordoned off completely, but traffic control points are established to divert traffic well away from the incident area.

The actual HazMat zone is then established inside zone 1 by the specialists from the HazMat unit. In order to keep potential contamination to a minimum, this zone should be as small as possible without putting emergency services personnel in any unnecessary danger. As the amounts and properties of the substances involved are of central importance in evaluating space requirements, this evaluation should only be carried out by persons with relevant chemistry knowledge and chemical incident experience.

In addition to the provisional decontamination station at the perimeter of zone 1, a professional decontamination station is established at the exit point on the perimeter of the HazMat zone where rescued people, emergency services personnel and material can be decontaminated (Fig. 1).

4. Principles of Decontamination

Time is a crucial factor in decontamination, with the principle of speed rather than perfection being particularly applicable to the decontamination of persons. In spite of the speed required, close attention should be paid that contamination is not transferred to uncontaminated areas.

If contamination cannot be ruled out completely at a chemical incident, a provisional decontamination station with water supply should be established at the perimeter of zone 1 by the first unit to arrive at the scene.

If in doubt, it is always better to decontaminate one time too many than too few.

5. Decontamination of Casualties

All persons leaving a contaminated or potentially contaminated zone must be checked for contamination at the decontamination station. All cases of suspected or actual contamination should undergo immediate decontamination.

The first priority, however, is to rapidly evaluate casualties using the ABCs of first aid. For example, it makes no sense to thor-

oughly decontaminate a casualty if he or she has already stopped breathing.

If contamination is suspected, an additional check for chemical burns, thermal burns and poisoning is carried out.

Uninjured persons or those showing no symptoms should at least remove all affected items of clothing and thoroughly clean all potentially contaminated skin areas with soap and water. Intensive mechanical cleaning, such as scrubbing with a brush, should be avoided as this can damage the skin and lead to chemicals being absorbed more quickly. Similarly, lukewarm and not hot water should be used for cleaning, as hot water causes the pores to open, which also promotes absorption.

Pressure washers are helpful for decontamination of materials but not for decontaminating persons. In view of the high risk of injury involved, this procedure is completely inappropriate [1].

One often-debated question is whether spent decontamination fluid must be collected. The simple and logical answer is that if a person has been contaminated with chemicals, this must have been caused by a release of chemicals, and the amount released will always be significantly greater than the amount on the casualty's skin. It therefore makes no sense expending large amounts of time and energy collecting decontamination fluid.

In practice, either during exercises or a real emergency, the most frequently observed errors are:

- Time being lost as a result of too much talking.
- Failure to have casualties remove all affected items of clothing, *e.g.* shoes, socks and underwear.
- Failure to recognise that contaminants may be deposited on the inside of rescue-masks worn by casualties.
- Clean body areas being contaminated unnecessarily as a result of incorrect procedures.
- Overreaction, *i.e.* decontaminating all persons who were in the zone without first carrying out a triage. If the number of persons is large, decontamination facilities can rapidly become overstretched, which in turn can prevent the 'real' casualties from receiving proper treatment.

The rescue chain can be split up into four phases:

Phase 1:
Removal/First Aid by the Fire Service
Taking suitable precautions to ensure their own safety, fire service personnel remove the casualty from the contaminated zone as quickly as possible in order to limit exposure to the hazardous substance. Life-saving measures are initiated.

Fig. 2. Decontamination of a HazMat unit member in a protective suit. In most cases water is a suitable decontamination reagent.

Phase 2:
Gross Decontamination/First Aid by the Fire Service
The effect of the harmful substance on the casualty is reduced by removing all affected clothing and washing the skin. This eliminates the risk to persons outside of zone 1.

Phase 3:
Secondary Decontamination by the Fire Service, Ambulance Service or Samaritans (Volunteer Emergency Service)
The affected body areas receive further treatment specific to the hazardous substance. The aims are to prevent both the casualty's condition from worsening and contamination of the transport vehicle and hospital.

Phase 4:
Transport by Hospital or Fire Service Ambulance or REGA (Swiss Air Rescue)
Supervised transport to a hospital or doctor's office.

6. Decontamination of Emergency Services Personnel

In the event of skin contact or suspected or actual contamination of fire protective clothing, emergency services personnel should be treated identically to other casualties (Fig. 2).

7. Decontamination of Vehicles and Equipment

To keep decontamination work to a minimum, only absolutely essential materials and equipment should be taken into the contamination zone.

A station should be set-up and marked at the perimeter of the HazMat unit zone or zone 1 where all material can be checked and, if necessary, undergo at least gross cleaning before leaving the zone.

Cleaning with water, soapy water or a neutralisation solution is sufficient in most cases, apart from those involving extremely toxic or environmentally hazardous chemicals, where the appropriate cleaning method should be selected by a suitably qualified person.

'Dry cleaning', which is common for radioactive decontamination, is, at most, suitable for use with substances that react very strongly with water, *e.g.* sodium. However, wet cleaning must still be carried out following gross dry decontamination.

Small items of equipment should be packed in plastic sacks after gross decontamination and brought to a suitable place for secondary decontamination.

If items of personal protective equipment such as gloves, boots or fire protection jackets are contaminated with critical or poorly water-soluble substances, they must be incinerated. Depending on the chemicals involved, disposal in a special waste incinerator may be necessary.

Protective suits contaminated with water-soluble materials can be cleaned using plenty of water and used again following drying and inspection. If, however, the suits have come into contact with chemicals which can only be removed using aggressive chemical or mechanical cleaning methods, for safety reasons they must be disposed of in an appropriate incineration plant.

8. Case Histories

Case 1

A faulty hose line resulted in a chemical worker being splashed with concentrated sodium hydroxide solution. Instead of going straight to the emergency shower, he went to the infirmary where he was immediately (correctly) decontaminated using large amounts of water. He then put his work clothing back on and prepared to leave. Just at this moment the author of this article arrived and almost instinctively checked a damp patch on the man's clothing using pH paper. The paper turned dark blue immediately, indicating that the clothing was still soaked with sodium hydroxide solution. The work clothing was removed again immediately and decontamination of the skin was repeated.

- Never put contaminated clothing back on.
- Infirmaries should always have spare outer garments and underwear available. Spare clothing should also be carried by emergency services vehicles.

Case 2

As a result of an error a chemical worker sprayed himself with chlorobenzene. At the infirmary all clothing was removed immediately and placed in a plastic sack. The worker was rubbed from head to toe under the shower with polyethylene glycol and rinsed down with lukewarm water and soap. This process was repeated (6 times) until practically no odour could be detected on the skin.

- Always have polyethylene glycol 400 available for use with poorly water-soluble substances.
- Consider how best to determine if decontamination has been successful.
- Use only lukewarm and not hot water.

Case 3

During a chemical incident two chemical workers were sprayed over much of their bodies with a poorly water-soluble phenol derivative. Following initial gross decontamination using water, soap and polyethylene glycol, arrangements were made for the casualties to be transported to hospital. The ambulance personnel were given 5 l of polyethylene glycol and verbal instructions for secondary decontamination at the hospital.

- Hospitals that are not specialised in dealing with chemical incidents have neither sufficient specialist knowledge nor suitable decontamination materials. Precious time can be lost if hospital personnel have to hunt down information.

Case 4

A case is imaginable where a small area on the thigh contaminated with phenol was incorrectly decontaminated using ethanol. The casualty could die as a result of the increased absorption caused by the harmful material being spread over an area >100 cm^2 [2].

- Under no circumstances should solvents such as ethanol, acetone or benzene be used to clean skin.

9. Equipment

HazMat specialists and occupational physicians have developed commercially available kits that contain the equipment and supplies needed for decontamination and administering first aid for chemical burns, thermal burns and poisoning.

10. Training

Experience shows that correct decontamination measures can be very complex. In the wrong situation, thinking that one can get by with a little bit of 'theory' can have disastrous consequences. When carrying out decontamination exercises, it is imperative that food colouring or some other visible agent be used as a 'contaminant' so that the success of the measures employed is obvious. This is the only way in which thorough removal or undesired transfer of the contaminant can be identified. If, after a decontamination exercise, colour is found on the door handles and seats of the emergency services vehicles, the exercise should definitely be repeated.

Received: November 19, 2003

[1] vfdb, Vereinigung zur Förderung des deutschen Brandschutzes, 'Richtlinie Dekontamination bei Feuerwehreinsätzen mit gefährlichen Stoffen und Gütern', vfdb-Richtlinie 10/04, **1998**.

[2] BASF, Aktiengesellschaft, 'BASF Medizinische Leitlinien bei akuten Einwirkungen von chemischen Substanzen, Phenol (C6H5OH)', **1999**.