eNOTICE-2
EU Network of Training Centres for preparedness to CBRN Events

Decontamination of assistive devices

Scope of this document

This document focuses on the topic of decontamination and, in particular, the handling of assistive devices used by vulnerable groups of population – people with disabilities. During the CBRN emergency response, the **decontamination of** individuals, in particular of **people with disabilities**, presents unique challenges that require treatment of **assistive and supportive devices** to ensure their safe re-use after the decontamination. The UCPM KAPP project eNOTICE-2 addresses these challenges by equipping first responders, including firefighters, civil protection and emergency health responders, with the necessary tools and knowledge to effectively decontaminate individuals with disabilities and assistive devices. This document outlines the **decontamination methods for assistive devices employed in Germany, Belgium, and the United Kingdom, strategies adopted by military organizations, and emerging methods of decontamination**.

Decontamination of assistive devices

The topic of 'CBRN hazard defence' is very diverse and extensive. Describing all aspects and facets of dealing with a CBRN incident takes on very large dimensions and is not the focus of this document. In the following sections, the focus is on the topic of decontamination and, in particular, the handling of assistive devices for vulnerable groups. In the following, examples of how the topic is dealt with in the respective countries are given based on the input of each partner involved. The aim here is not to provide a comprehensive description, but to show which initial approaches already exist and where they originated.

Germany

Fire Departments

A basic plan for German fire departments to be prepared for CBRN accidents is regulated by Fire Service Regulation 500 (*Feuerwehr-Dienstvorschrift - FwDV 500*). It includes a series of measures to ensure that the emergency services and their equipment are ready for action and adequately prepared for potential hazards. The relevant topics of the FwDV 500 consist of the following sections:

I. General guidelines

1. General information about hazardous substances
    - Risk due to hazardous substances
    - Preparatory measures

- Special equipment (incl. Measuring devices)
- PPE
- Training
- Operation
  - Reconnaissance
  - Gathering information
  - Situational assessment
  - Definition of areas
  - Decontamination (injured, equipment, staff)
- Structure of units during CBRNe operation
  - Tasks of rescue units within the CBRN operation

II. Special guidelines

2. Special regulations concerning RN-Operations
   - Tasks of units
   - PPE
   - Measuring devices
3. Special regulations concerning B-Operations
   - Tasks of units
   - PPE
   - Measuring devices
4. Special regulations concerning C-Operations
   - Tasks of units
   - PPE
   - Measuring devices

III. Attachments

- Glossary
- 4-A Rule for the CBRN-operation
- Decon matrix for the Fire Department
- Demarcation of risk areas
- …

One of the most important aspects of preparedness is the training of emergency responders. This training includes theoretical knowledge about different types of hazardous substances, their properties, risks and handling, as well as practical training in the use of specialized equipment and emergency decontamination procedures.

Process of decontamination:

The process of decontamination is divided into three levels. These are used for different scenarios, which are explained in the following section.

Level 1 – Instant decontamination:

The first of the three levels is instant decontamination. This level is used in the first phase of the operation and can be done with the help of any fire truck. For example, this level may be necessary if a person needs to be rescued without any advanced CBRN equipment. Setting up

the decontamination equipment must be finished at the same time as the first rescue team enters the hazardous area.

The target of instant decontamination is to gross decontaminate injured persons as quickly as possible. To do this, the person is washed with water on a tarp and is undressed. This ensures that immediate life-saving measures can be carried out without endangering yourself or others.

Level 2 – Standard decon:
For the standard decontamination, the fire department uses advanced CBRN equipment. This is carried out by a special decon unit of the fire department. It must be set up after 15 minutes, from the time the first special team of CBRN-units enters the hazardous area. In contrast to the level 1, the standard decontamination is divided into a separate black and white area. The black area has separate stations for undressing and a shower, that is used for the decontamination. After the successful decontamination, the person can enter the white area.

Level 3 – Extended decon:
For contaminated persons without life-threatening injuries, decontamination level three is set up. This stage can also be necessary for special hazardous substances, large numbers of injured people or for adverse weather conditions. Some additional advantages of extended decontamination are the ability to use hot water and to collect large volumes of wastewater in the decon area. For this purpose, a container tent solution is set up in which both mobile and lying persons are professionally decontaminated. Hot water treatment, changing facilities and, depending on the hazardous substance, disinfection facilities are available for this purpose. If a person is not able to walk, they are pushed through the decontamination route lying on a spineboard with the help of a roller system.

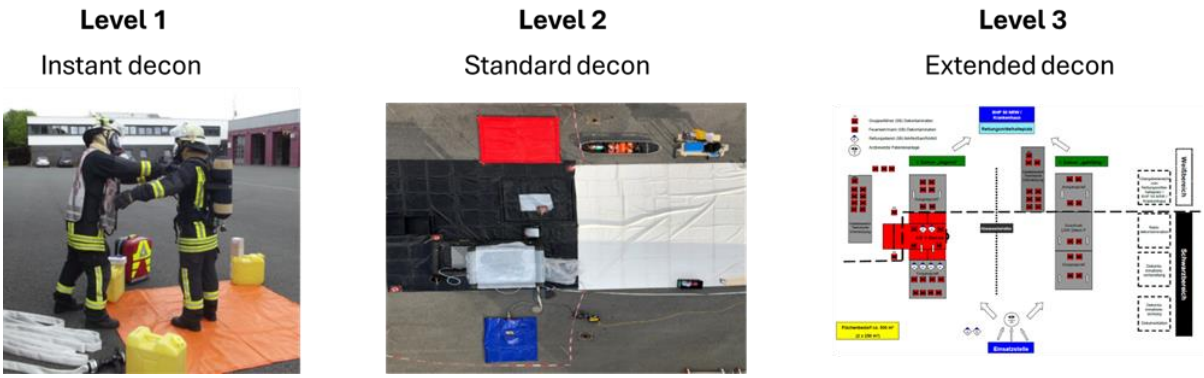


Figure 1: Process of decontamination (Source: FDDO)

In the first moments of a hazardous substance incident, emergency responders cordon off a radius of at least 50 meters around the accident site. This area is known as the hazardous area. Only those emergency personnel with special equipment who need to work there are allowed to be present in the hazardous area. However, these distances are only a rule of thumb and must be increased and modified if the hazardous substance spreads due to wind or topography. A radius of at least 100 meters around the hazardous area marks the shut-off zone. The equipment, specialized vehicles and personnel required for the operation are located inside the shut-off zone.

The decontamination area for the emergency services is located at the boundary of the two areas. The decontamination station for contaminated persons is located next to it or separately. The yellow area indicates the patient tray for people who will be decontaminated later.

Contaminated casualties with life-threatening injuries are still quickly and roughly cleaned via decontamination level 1 and transported to a hospital, as saving their life generally outweighs the remaining risk posed by small quantities of hazardous substances.

Overview of decontamination intervention

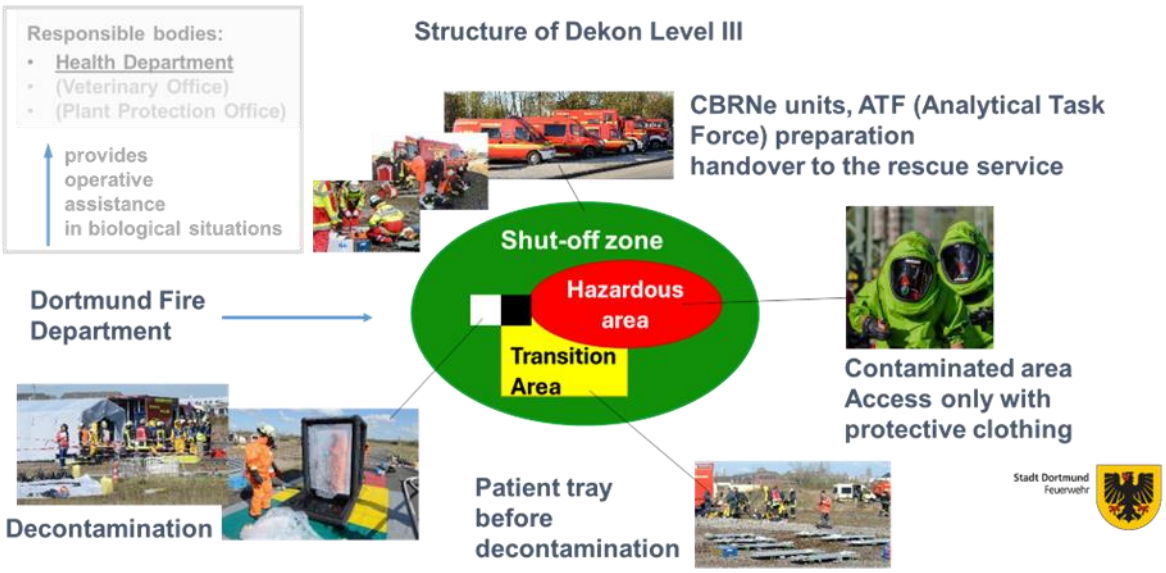
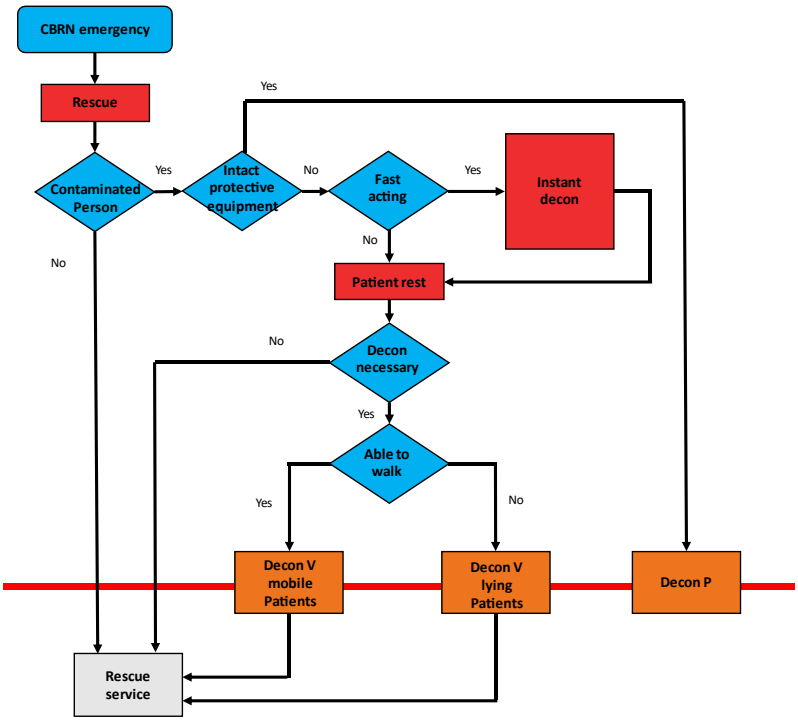


Figure 2: Decontamination areas (Source: FDDO)

Overall, the FwDV 500 ensures that the operation is carried out according to a structured and professional approach in order to effectively manage hazardous situations and ensure the safety of people, the environment and property. By adhering to these standards of the FwDV 500, emergency services can respond safely and effectively to dangerous situations and help to save lives and minimise damage.

Different decontamination lines

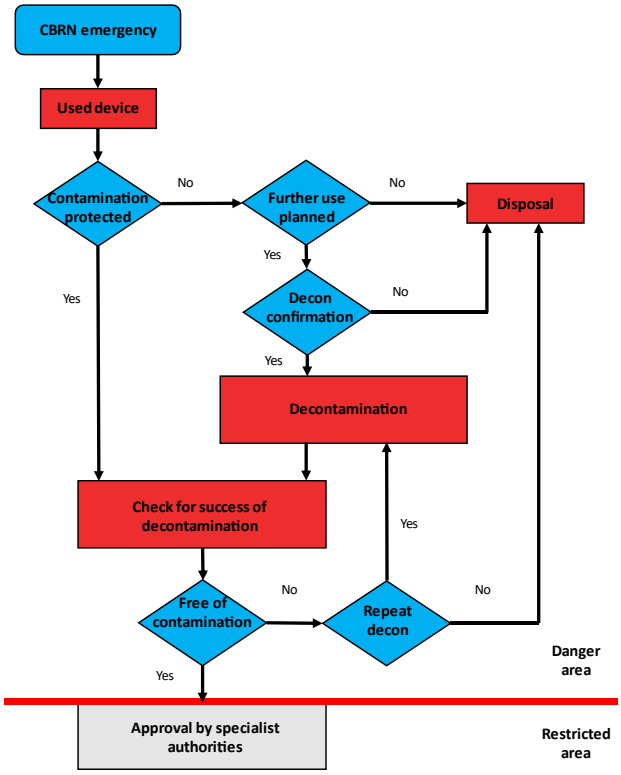
The following is a flow chart showing an example of a decontamination decision path.



Persons (P):
All persons who have worn intact protective equipment

Injured persons (V):
All persons who were unprotected in the contaminated area

Figure 3: decon of people (incl. injured people) (Source: FDDO based on Ehrmann et al. 2020[1])



Differentiation between:
- Robust devices (Tubes)
- Sensitive devices (Radio Comms)
- One-time-use devices (Disposable protective suits)

Procedure for sensitive devices:
- Remove adhering substances with binding cloths
- Wash carefully with wetting agent solution or solvent
- Final cleaning

Figure 4: Decon of devices (Source: FDDO based on Ehrmann et al. 2020[2])

[1] K. Ehrmann, A. Kühar: CBRN Schutz in der Gefahrenabwehr – 1.Auflage - ISBN 978-3-17-030975-3 – Kohlhammer, Stuttgart – 2020

[2] K. Ehrmann, A. Kühar: CBRN Schutz in der Gefahrenabwehr – 1.Auflage - ISBN 978-3-17-030975-3 – Kohlhammer, Stuttgart – 2020

The correct selection and use of specialised equipment and measuring devices is crucial for the success of operations. Training, provision of equipment and development of operational plans ensure that the emergency services have the necessary skills, knowledge and resources to successfully fulfil their tasks. FwDV 500 places great emphasis on the provision of specialised equipment, including measuring devices, to assist the emergency services in dealing with hazardous situations involving dangerous substances and goods. This equipment plays a crucial role in recognising, analysing and assessing hazards and in implementing emergency response measures. Some examples of measuring devices are:

Gas detectors:
Gas detectors are portable measuring devices used to measure the concentration of hazardous gases in the ambient air. They can detect various gases such as carbon monoxide, carbon dioxide, oxygen deficiency and combustible gases. Gas detectors enable emergency services to recognise potential hazards at an early stage and react appropriately, for example by determining the need for respiratory protection or the evacuation of people from contaminated areas.

Radiation detectors:
Radiation detectors are used to measure radiation levels in the environment. They can detect different types of radiation such as alpha, beta and gamma radiation and measure their intensity. Radiation detectors are particularly important in operations involving radioactive materials, such as accidents in nuclear power plants or the transport of radioactive substances.

Chemical analysers:
Chemical analysers are portable devices used to analyse the composition of chemical substances. They can be used, for example, to identify unknown substances or to determine the concentration of certain chemicals in the air or on surfaces. This information is important for assessing hazards and determining suitable protective measures.

Federal Police

In addition to the fire department, the federal police also possess a decontamination unit. It uses tents in a similar way to the fire department. In contrast to the fire department, this decon unit is only used for tasks during police operations. This includes the decontamination of emergency personnel and of injured persons. Other tasks are the decontamination of evidence and repackaging it in transport containers or the decontamination of persons who are subject to police measures.

For future operations the federal police is currently searching for better decon methods. The main reason being their current decon equipment requires too much set-up time. Further disadvantages are the high personnel approach and the dependence on the weather.[3]

[3] https://media.frag-den-staat.de/files/foi/850136/bpoldekon.pdf [21.06.2024]

Tasks during police operations:

- Decontamination of emergency personnel (also of injured persons)
- Decontamination of evidence and repackaging in transport containers
- Decontamination of Persons who are subject to police measures

Problems:

- Depending on weather conditions
- Set-up time
- Personnel approach

Figure 5: Decon-unit Federal Police[4]

To find a better solution the federal police is a member of the project funded by DG ECHO rescEU mechanism. The goal of this project is to create a supra-local CBRN-decontamination capacity that can be activated when the capacity of an EU Member State is insufficient.

The project leader is the Federal Agency for Technical Relief. The other project partner is the Federal Office of Civil Protection and Disaster Assistance. The rescEU decon unit in Germany is one of three projects which are funded by the EU for the time period May 2022 to 2026.[5]

- From May 2022 to 2026
- 100% EU funding with a total budget of 37.5 million euros

Technisches Hilfswerk
BUNDESPOLIZEI
BBK Bundesamt für Bevölkerungsschutz und Katastrophenhilfe

The unit will consist of 300 emergency personnel, 30 trucks and around 30 vehicles (trailers and minibuses)
It will consist of four modular parts:
1st unit - Decontamination of infrastructure (buildings and roads)
2nd unit – Decontamination of vehicles
3rd unit – Decontamination of small devices or packages containing evidence
4th unit – Decontamination of capable of walking and non capable of walking persons

Belgium

For as far as the legal framework for dealing with CBRNe (de)contamination is concerned, reference is made to the relevant documents in point 2.2.1.

It needs to be said that Belgium – on a federal level – is reviewing its approach to the CBRNe (de)contamination. The National Crisis Centre of the country is currently developing a CBRNe

[4] https://media.frag-den-staat.de/files/foi/850136/bpoldekon.pdf; https://www.bfs.de/SharedDocs/Kurzmeldungen/BfS/DE/2019/0520-zub-praxisschulung.html; https://www.ln-online.de/lokales/herzogtum-lauenburg/ratzeburger-bundespolizei-gut-geruestet-OMRGL3PW5QDX22EZQCEF6A36UA.html [21.06.2024]

[5] https://www.thw.de/DE/Im-Einsatz/Ausland/Internationale-Zusammenarbeit/Projekte/_documents/cbrnecon.html; https://www.bundespolizei.de/Web/DE/04Aktuelles/01Meldungen/2023/02/230221-cbrn.html; https://www.bbk.bund.de/SharedDocs/Pressemitteilungen/DE/2023/02/pm-21-resceu.html [21.06.2024]

doctrine, that will form the framework for further operationalisation. This means moving away from regional and zonal SOPs and procedures towards national SOPs and procedures.

The information contained in this deliverable thus shows an example of how decontamination could be arranged in one region. In this, we tried to use as much information that is applicable to all or multiple regions.

Nonetheless, it is important to consider that this information is prone to change and adaptation.

Relevant documents

- Royal decree establishing a national emergency plan for tackling a criminal incident or a terrorist attack involving chemical, biological, radiological or nuclear agents (CBRNe)[6] (sensitive- not publicly available)
- Royal decree establishing a nuclear and radiological emergency plan on Belgian territory[7]
- Royal decree amending the royal degree of 10th of June 2014 determining the missions and tasks of civil security carried out by the emergency response zones and the operational units of Civil Protection and amending the Royal Decree of 16 February 2006 on emergency and intervention plans[8]

Working together

The two main governmental organisations dealing with decontamination, are the fire department and the civil protection.

The fire department in some regions (zones) is in possession of a decontamination unit/ shower that allows for small-scale decontamination.

The civil protection is responsible for the coordination of mass decontamination and is in possession of decontamination equipment with a larger capacity. In addition to that, possibilities of cooperation (amongst others within the scope of public private partnerships) are being looked at. The ratio of the latter is that private companies often have a more thorough knowledge and experience than the public organizations (e.g. in dealing with wastewater).

Apart from operational on-site decontamination, other guidelines exist for dealing with decontamination in e.g., hospitals.

[6] https://crisiscentrum.be/nl/documentation/wetgeving?search_documents=CBRN [21.06.2024]

[7] https://crisiscentrum.be/nl/documentation/wetgeving/1032018-koninklijk-besluit-tot-vaststelling-van-het-nucleair-en [21.06.2024]

[8] https://etaamb.openjustice.be/nl/koninklijk-besluit-van-20-september-2017_n2017013459.html [21.06.2024]

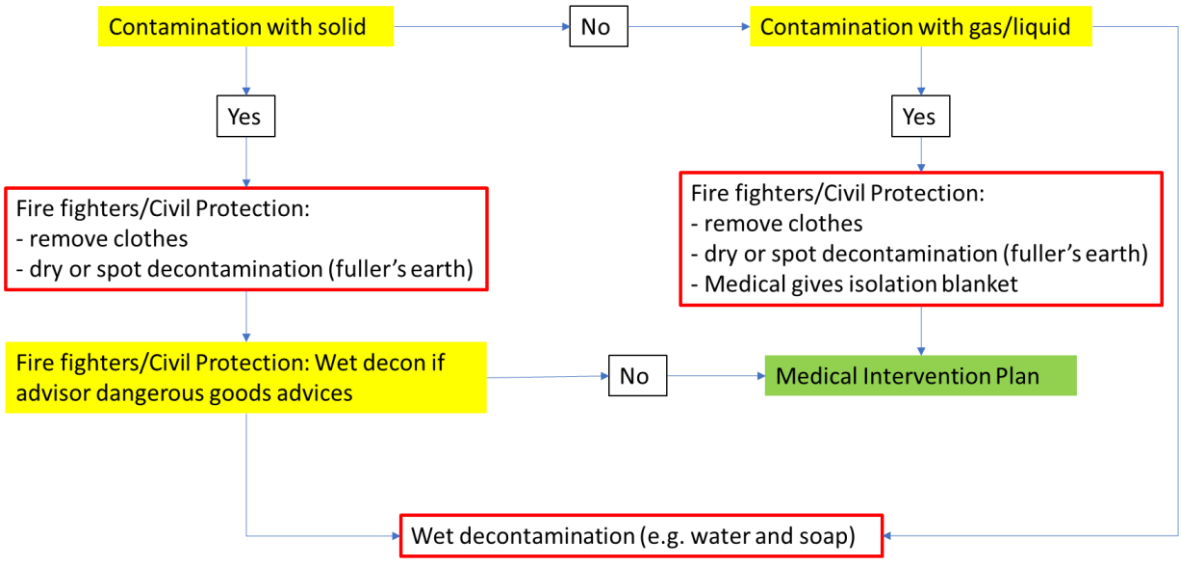


Figure 6: Flow of decontamination for the medical discipline[9]

Figure 6 shows the decision tree of decontamination as it is written down in the CBRNe guidelines for hospitals in Belgium. It describes the following steps.

- Reception of patient in the decontamination zone. A doctor performs a quick triage to see if immediate medical intervention is necessary. In the starting phase, this task can be performed by a firefighter paramedic.
- The patient is undressed in the undressing zone. For gas or vapor, this might be the only step necessary
- The advisor for dangerous goods decides whether wet decontamination is necessary. This could be when:
    - Contamination via a liquid or solid substance, inclusive powder and mist via the air.
    - Exposure to a gas or vapor if sufficient gas has remained or dissolved on sweaty skin. An indicator of this could be redness due to corrosive or irritating substances.
    - Exposure to gas, even with small exposure if there is still risk due to the high toxicity of the substance (e.g. CWA).
    - There is doubt whether the patient should be decontaminated.
- Wet decontamination takes place in the shower rooms. This could be done laying on a stretcher. Armpits, skin folds and palms should be rinsed well.
- Drying the patient of and transporting them to a clean room
- Further medical treatment
- Descaling decontamination team

[9] leidraad ziekenhuis: https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/crbn_znp_compressed_1.pdf [21.06.2024]

They also highlight that an external contamination should not transform into an internal contamination during the decontamination process and that communication with the victim is crucial. The privacy of the victim is also a point of interest.

The victims are also provided with clothing after they have gone through the decontamination.

Fire department

The fire department and civil protection both have – as stated before - decontamination equipment. They share the same SOPs with regards to IGS (incident with dangerous goods) and HAZMAT suits. On top of that, they share the same SOP with regards to setting up a decontamination field. The difference is that the fire department mostly works for improvised on site decontamination of a small-scale incident. This includes the decontamination of their own HAZMAT responders. The figure below shows the layout decontamination field.

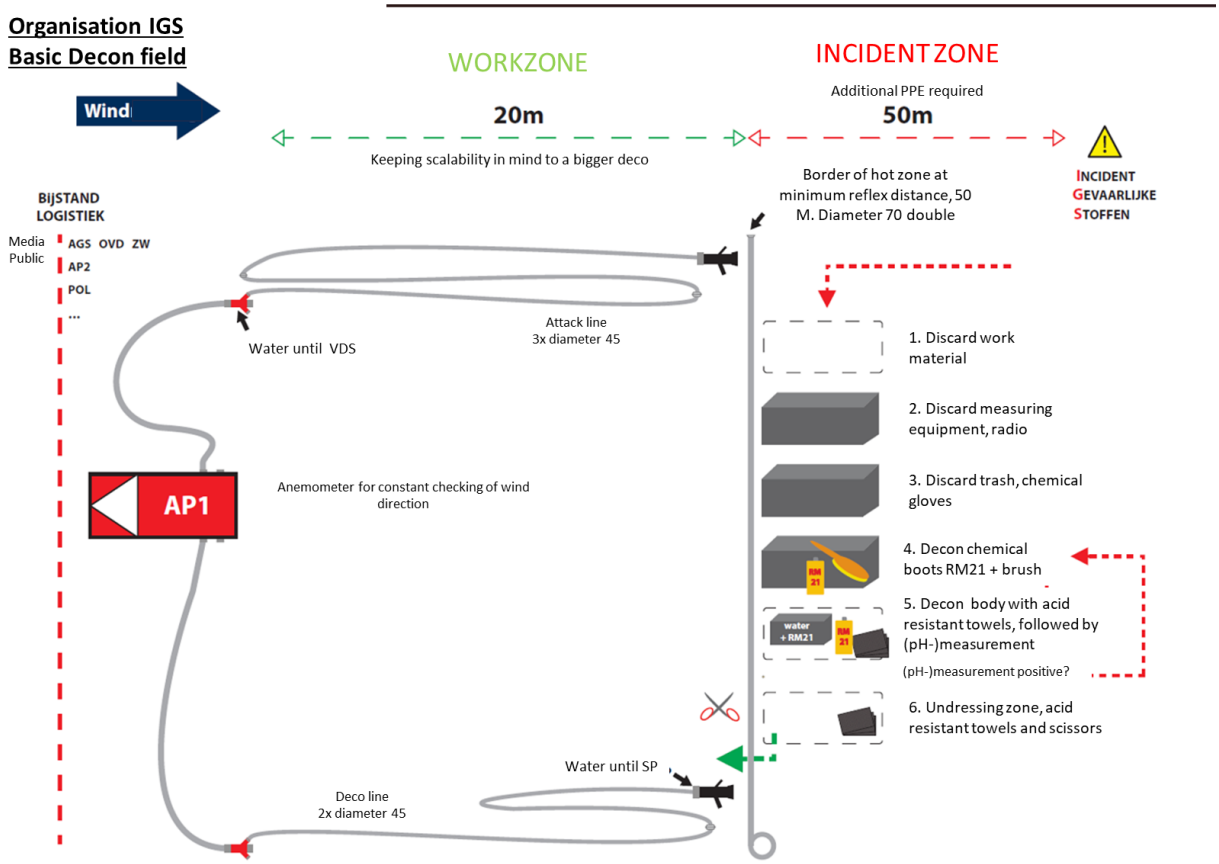


Figure 7: Basic decon field for dangerous goods, firefighters (Source: Vesta)

Civil protection

Levels of decontamination

Decontamination of personnel with a decontamination container[10]

[10] https://www.civieleveiligheid.be/sites/default/files/explorer/partie_protection_civile/cataloguemodulepc_12_23_nl.pdf , p 35-39 [21.06.2024]

This is a small mobile container or tent, mean to decontaminate personnel that have worked in the hotzone in HAZMAT suits.

Figure 8: Decontamination unit for Hazmat personnel, civil protection (Source: Vesta)

Mass decontamination

There are two approaches towards mass decontamination. It is split up in a small mass decontamination and a large mass decontamination. The methodology for the large mass decontamination is being re-considered and being developed, but this deliverable will show some of the preliminary ideas.

For small mass decontamination, a mobile unit can be called. The Fig. 9, show the mobile mass decontamination unit that can be set up during an incident. It has two sides, one for people that can walk and one for people that cannot. For large mass decontamination, the idea is that stationary existing buildings will be used. In this case, these facilities have many showers (some more than 60). It is either cut off from the sewers, or it can be cut of easily. The wastewater than get processed by a private company. Civil protection will coordinate in this case, but other organisations are still putting in effort. For example: the red cross for shelter of decontaminated victims, the municipality for fences and other logistic support etc.

Figure 9: Mass decontamination mobile unit, civil protection (Source: Vesta)

Decontamination of vehicles (high pressure and steam cleaning system, pool for water collection)

The decontamination of vehicles can be done by placing the vehicle in a container and filling that container with 160 degrees of Steam. On top of that, there is a device (pictured below), that can be used outside of the container and that also produces 160 degrees steam. This method however is not safe for electronic devices or assistive devices that cannot withstand that heat. There is currently a discussion surrounding the decontamination of devices of the different disciplines. The outcomes of that discussion could also be of use for assistive devices of vulnerable people.

Figure 10: Equipment to decontaminate equipment and vehicles, civil protection (Source: Vesta)

United Kingdom

In the United Kingdom, whilst no specific decontamination procedures currently exist for disabled or neurodivergent people or groups of people, or any assistive devices they may use, the need to consider the specific needs of various vulnerable groups when responding to a CBRN event is set out in the guidance publication *Initial Operational Response (IOR) to Incidents Suspected to Involve Hazardous Substances or CBRN Materials*[11].

IOR recognizes that vulnerable people (not only those with disabilities or neurodivergence) can have different physical, communication, health, or cultural needs which need to be considered by emergency responders. IOR recommends considering the potential *functional* needs of vulnerable people, when planning for the management of IOR.

IOR separates peoples' functional needs into four broad areas:

- Impaired ability to physically react to a hazardous substance incident or undergo decontamination (e.g., any factors which make it physically challenging for individuals to undergo decontamination).

[11] National CBRN Centre, Coventry, UK, Version 1.1, June 2024

- Impaired ability to communicate during a hazardous substance incident or the decontamination process (e.g. any factors which make it difficult for individuals to hear, see, or understand instructions provided).
- Different social or cultural needs (e.g. cultural norms or religious norms).
- Pre-existing health factors or medical conditions (e.g. any factors which may make people more susceptible to the effects of contamination, or pre-existing conditions for which people need medication).

IOR emphasises the importance of understanding that the public perception of how the emergency services and other responder organisations interact, communicate and support vulnerable people, may be as significant as the impact of their actions themselves.

IOR also emphasises the importance of considering how responders and commanders identify, communicate and interact with vulnerable people during any response, ensuring that instructions are accessible, inclusive, actionable by all, timely and understood.

In relation to assistive devices, IOR recognises that there may be times when mobility equipment or assistance animals are present, and consideration should be given as to how they are managed during IOR. For example, IOR emphasises the significant, detrimental effect that the removal or retention of mobility equipment may have on users, necessitating responders to take a considered and pragmatic approach, supported by scientific advice, when dealing with such equipment.

IOR also recognises that the decontamination of service animals is a specialist activity requiring specialist resources and considerations. IOR again emphasises the importance of seeking scientific advice at the earliest opportunity in incidents where contaminated animals need to be managed.

Other (military sector)

The decontamination process involves reducing, neutralizing, or removing hazards from chemical, biological, radiological and nuclear (CBRN) substances that have accumulated on equipment and personnel. When prevention, precautionary and control measures fail to manage the hazard effectively, decontaminating personnel, equipment and materials becomes necessary. In certain cases, this may also extend to static installations and logistical facilities. Several principles guide the decontamination process:

- Timelines: Decontamination should occur as soon as possible to minimize exposure and spread of contaminants.
- Necessity: Only decontaminate what is essential, based on operational requirements.
- Proximity: Perform decontamination as close to the contamination site as possible to limit the spread of hazardous materials. The decon station must be installed at a toxic free, clean area.

- Prioritization: Prioritize decontamination efforts based on the level of threat and operational impact.
- Planning: decontamination plan should be developed (number and layout of decontamination stations, needed equipment, suitable decon method for CBR contamination, personal protective equipment, medical care, logistic support for decontamination material).

Decontamination may be either passive or active, depending on the urgency of the situation:

Passive Decontamination

Also known as 'Natural Decontamination' or 'Weathering,' passive decontamination relies on natural processes such as weathering or decay to mitigate hazards without human or mechanical intervention. While this method is time-consuming, it requires minimal manpower and logistical resources. Its effectiveness depends on environmental conditions like temperature, humidity, and wind, as well as the properties of the contaminated material and the type of contaminant. Items undergoing passive decontamination should be isolated and marked to indicate they pose a hazard.

Active Decontamination

Active decontamination involves using chemical, biological, or mechanical processes to remove or neutralize CBRN substances. This method is employed when contamination significantly impairs operational capabilities. Active decontamination is categorized into three levels:

Immediate Decontamination: Quick actions taken to save lives and prevent further contamination spread.

- Operational Decontamination: Measures that sustain operations by reducing the hazard to an acceptable level.
- Thorough Decontamination: Detailed decontamination that restores operational capabilities and ensures long-term safety.

Decontamination Procedures and Techniques

Military decontamination procedures typically **do not include specific techniques for assistive devices**. Standard decontaminants—comprising various liquids, slurries, foams and powders—are used to encapsulate, absorb, remove, neutralize or diminish CBRN hazards. These methods are applied, as much as possible, to assistive devices when necessary. While decontamination is performed to protect health and safety, it can pose hazards under certain circumstances.

Civilian-Military Cooperation

Collaboration between civilian and military authorities is crucial for addressing the unique requirements of decontaminating assistive devices. Military authorities will evaluate the potential contribution of decontamination units in supporting these efforts, based on their capabilities and operational parameters.

<u>Equipment Considerations</u>

All equipment must be considered during decontamination. Some items may not be decontaminable and will need to be destroyed in a manner that minimizes waste. Alternatively, such items can be left in a designated weathering area to undergo natural decontamination processes.

Sensitive equipment (SE) includes items (e.g. computers and electronics) that cannot be decontaminated using standard methods, such as aqueous or organic-based liquid decontaminants, without compromising their performance, function. Sensitive equipment is also defined as material or equipment critical for military mission success, with functions essential to the system's effective operation.

Certain materials are deemed sensitive due to their chemical composition and their position within the system, such as interfaces between sensitive electronics. SE may not withstand exposure to CBRN substances or be suitable for common decontamination processes, potentially leading to degraded performance. Additionally, decontamination solutions or processes may not be effective if the decontaminant cannot reach the contaminants on or within the SE and a residual hazard remains.

When designing the system, it is crucial to identify sensitive equipment to plan for its operation in CBRN-contaminated environments. This approach ensures that SE is adequately protected and that effective decontamination measures are in place, preserving the functionality and safety of the entire system.

In summary, effective decontamination is essential to maintaining operational readiness and safety in environments where CBRN hazards are present. By adhering to established principles and leveraging both passive and active methods, military and civilian entities can work together to mitigate these threats.

Decontamination of sensitive materials in various environments, including military, industrial and emergency response settings, is a critical task that requires effective and reliable solutions.

Sensitive materials, such as electronic devices, medical equipment and communication systems, are crucial in many operational contexts. Their contamination by chemical, biological, radiological and nuclear (CBRN) agents can lead to severe consequences, including equipment failure, data loss and health hazards. Effective decontamination ensures the functionality and safety of these materials, thereby maintaining operational integrity and safeguarding human health.

Some decontamination methods with the potential to decontaminate assistive equipment can be used in various decontamination systems:

- Gaseous methods (e.g., hydrogen peroxide).
- Enzymatic decontamination.
- Soft decontamination solution (peracid).
- Solvent-impregnated wipes.
- Thermal approaches.

- Vacuum techniques.
- pressurized multiphase (adsorbent, solvent/co-solvent and propellant) system.

The following chart provides a comprehensive overview of the existing decontamination methods and procedures.

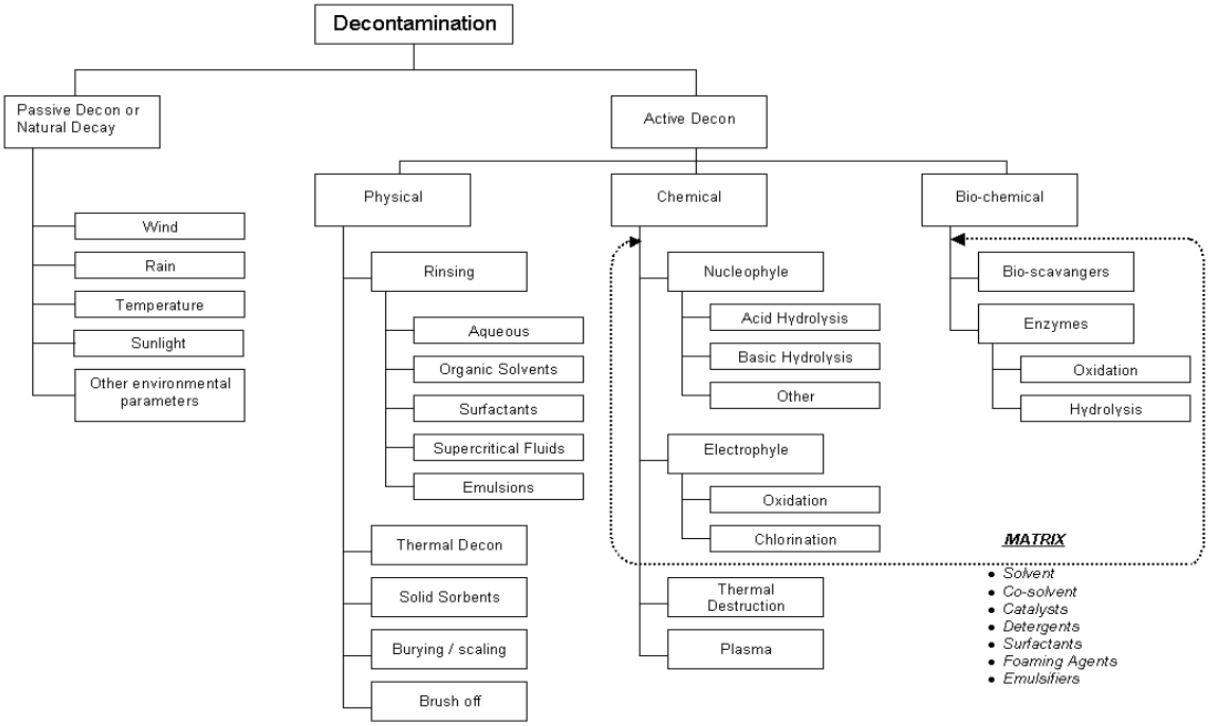


Figure 11: Decontamination methods and procedures chart (ANNEX A TO AEP-58, VOL 1)

Effective decontamination of sensitive materials involves using advanced formulations that combine both chemical and mechanical actions to neutralize contaminants. The process works through several key mechanisms.

Firstly, there's chemical neutralization. Decontaminating agents often contain active chemicals designed to react with CBRN contaminants, neutralizing their harmful effects. These chemicals break down complex contaminants into harmless substances without causing damage to sensitive materials.

Secondly, these formulations also facilitate the mechanical removal of contaminants. When applied, they form a protective layer that encapsulates the contaminants, making it easy to wipe or rinse them away.

Finally, compatibility with sensitive materials is crucial. Decontaminating solutions are specifically engineered to be non-corrosive and non-reactive with delicate materials. This ensures that electronic circuits, medical instruments and other sensitive components remain unharmed during the decontamination process.

Decontamination solutions are essential across various sectors, serving multiple critical purposes.

In the military and defence sector, equipment and communication systems often come into contact with hazardous substances. Decontaminating agents are crucial here, as they ensure that these critical assets are swiftly and effectively cleansed, maintaining operational readiness.

For emergency response teams, decontaminating agents are indispensable during chemical spills or biological threats. These agents cleanse protective gear and instruments, ensuring the safety of responders and the continued usability of essential equipment.

In healthcare settings, decontamination is vital to prevent the spread of infections. Reliable decontaminating solutions are used to cleanse sensitive medical devices, ensuring they remain functional and safe for use.

Finally, in industrial environments, where hazardous materials are frequently present, decontaminating agents play a key role in cleansing machinery and tools. This not only protects workers, but also helps maintain productivity by ensuring that equipment is safe to use.

Using effective decontaminating agents comes with several key advantages that make them invaluable in various situations.
Firstly, these advanced formulations are incredibly efficient. They provide rapid and thorough decontamination, which means minimal downtime and a quick return to normal operations. This efficiency is crucial in maintaining the flow of activities, especially in critical environments.

Safety is another major benefit. These decontaminating solutions are designed to be safe for both the user and the environment. By avoiding highly toxic chemicals, they ensure that the decontamination process does not pose additional risks, making them a responsible choice for various settings.
The versatility of these solutions is also noteworthy. They can be applied to a wide range of materials, which makes them suitable for different decontamination needs. Whether it's electronic devices, medical instruments or industrial machinery, these agents can handle the task effectively.

Lastly, the reliability of these decontaminating agents is backed by extensive research and field testing. Developed by experts in the field, they have been proven to perform consistently in critical situations. This reliability ensures that when decontamination is needed, these solutions can be trusted to do the job right.

Decontaminating sensitive materials is essential across many sectors. Effective, safe and versatile solutions neutralize and remove contaminants without harming delicate materials. These solutions are vital for maintaining the functionality and safety of critical equipment, safeguarding human health and ensuring operational integrity. As CBRN threats evolve, advanced decontamination solutions will continue to be crucial for protecting lives and maintaining readiness.

Emerging methods for decontaminating sensitive electronic devices

Effective decontamination is crucial for maintaining safety and readiness in CBRN environments. By following established principles and utilizing both passive and active methods, civilian and military institutions can mitigate these threats. Decontaminating sensitive assistive devices in various environments in emergency, military and industrial response is essential and requires reliable solutions.

Moreover, the document also explains the general decontamination procedure according to the latest standards from different institutions, covering preparation, equipment, PPE, training, operation sequences and the structure of emergency personnel. The FwDV 500 standard ensures for Dortmund operations are conducted professionally to manage hazardous situations and ensure the safety of people, the environment and property.

The eNOTICE-2 project aims to assess electronic-friendly decontamination methods by reviewing the state-of-the-art literature and gathering direct feedback from Research and Technology Organizations (RTOs) as well as small and large companies that are stakeholders in the project. A lecture on emerging decontamination technologies and the best candidates for decontaminating sensitive electronic devices was presented during the eNOTICE-2 Simulation Exercise (SimEx) at FDDO, Dortmund, in April 2024. A review summarizing the findings will be published during the project. The following Table summarizes the content of this lecture.

Table. Emerging electronic-friendly decontamination methods: main features.

Decontamination Method	Working mechanism	Effectiveness against biological agents	Pros	Cons	Impact on materials
		(Bacteria, enveloped and non-enveloped RNA or DNA viruses, endospores of *bacillus subtillis* and *bacillus thuringiensis*)			
Cold plasma	Highly ionized gas produces Reactive Species (ROS) that alter pathogen's genetic and protein material	Highly effective against viruses and bacteria but less effective against spores, particularly Bacillus subtilis.	- Non-chemical, environmentally friendly	- Can modify surface properties of polymers and rubbers	- Polymers (PP, PETG, Polyethylene, etc.) may experience surface modifications
			- Compatible with electronics and metals	- Requires specialised equipment	- Metals (Aluminium, Tungsten) generally compatible
		NB: The effectiveness of cold plasma against Bacillus endospores depends on several factors, including the type of cold plasma used (atmospheric or low-pressure), the exposure time, plasma power, and	- Operates at low temperatures	- Limited penetration in complex geometries	- Electronics generally stable but avoid prolonged exposure; certain materials might be more reactive or sensitive to the plasma-generated species than others
				- Potential material degradation with prolonged exposure	
UV-C	Direct Photochemical Damage: UV-C Light induces thymine dimers and inhibits microbial replication	Highly effective against viruses (especially enveloped) but <u>less effective against spores</u>.	- Safe for metals and most electronics with short exposure	- Heat Generation: some UV-C lamps can produce heat as a byproduct, which may be harmful to heat-sensitive electronic components.	- Polymers (PP, PETG, Polycarbonate) may yellow or become brittle
				- Limited penetration for shadowed areas	- Metals (Tungsten, Aluminium) are generally unaffected
				- Surface damage: Can degrade polymers and rubbers with prolonged exposure, causing discoloration, brittleness, and other forms of surface damage to sensitive electronic devices, potentially compromising their structural integrity.	- Not suitable for light sensitive electronic components Electronics plastic or rubber casings may degrade over time, which may affect the integrity and functionality of electronic components that are made from or contain these materials
Vaporised Hydrogen Peroxide (vHP, Dry HP vapour)	Oxidative Damage (ROS) to microorganisms' genetic material and proteins.	<u>Highly effective</u> against most pathogens, including spores (though moderately effective against Bacillus subtilis spores).	- Highly effective against various pathogens	- Requires specialised equipment	- Generally compatible with a wide range of materials, including plastics and metals if condensation on the surface is prevented
			- Can reach difficult areas	- Needs careful handling to avoid overexposure	- May not be suitable for electronics due to its corrosive nature and moisture content; not all materials used in electronic devices are compatible; Suitable for well-sealed and designed to be moisture-resistant or have protective coatings and if temporary or controlled exposure

Table. Emerging electronic-friendly decontamination methods: main features (continued).

Decontamination Method	Working mechanism	Effectiveness against biological agents	Pros	Cons	Impact on materials
		(Bacteria, enveloped and non-enveloped RNA or DNA viruses, endospores of *bacillus subtillis* and *thuringiensis*)			
(Bacteria, enveloped and non-enveloped RNA or+A16 DNA viruses, endospores of *bacillus subtillis* and *thuringiensis+A14:F21*)	Oxidative damage to microorganisms' cell walls and genetic material.	Highly effective against most pathogens, with lower effectiveness against non-enveloped RNA viruses and Bacillus subtilis spores.	- Penetrates hard-to-reach areas	- Corrosive to some materials (e.g., rubbers, certain metals)	- May damage elastomers, some polymers, and sensitive metals (e.g., silver)
			- Effective against a broad spectrum of pathogens	- Toxic to humans, requiring strict safety measures	- Risk of oxidation for electronic components; suitable only for well-sealed, moisture-resistant devices with protective coatings, and if exposure is temporary or controlled
Autoclave (steam sterilisation)	Heat and pressure induce denaturation of microorganims' proteins	Highly effective against all tested pathogen, including spores	- Extremely effective at eliminating all microorganisms	- Not compatible with heat-sensitive materials (e.g., electronics, certain plastics)	- Highly effective on heat-resistant metals and materials
			- Suitable for heat-resistant materials		- Can melt or deform heat-sensitive plastics and composites
Gamma irradiation	Radiation Induces DNA Breaks	Highly effective against all tested pathogen, including spores	- Deep penetration	- Requires access to specialized facilities	- May degrade certain plastics and rubbers
			- Effective against a wide range of microorganisms	- Potential material degradation, especially in plastics and rubbers	- Metals and electronics generally resistant but need controlled doses
Electron beams	Electron Beam Induces DNA damage and cellular disruption	Highly effective against viruses, bacteria, and spores, including Bacillus subtilis and Bacillus thuringiensis	- Rapid and effective sterilisation	- Limited penetration depth	- Some materials (e.g., certain polymers) may become brittle or degrade with exposure
			- No residual chemicals	- High equipement cost: this method requires specialised equipment and safety measures (shielding required to protect the operators)	- Metals generally unaffected; suitable for heat-sensitive materials
		NB: Electron beam effectiveness is generally high for surface sterilisation but may require adjustments in energy levels for deeper penetration or thicker materials.	- Can be precisely controlled for dose and duration	- This method can generate heat: Sensitive devices could be at risk if exposed to excessive heat during the process.F22	- Certain electronics or radiation-sensitive materials should be evaluated for compatibility; risk of damage to certain electronic components if not adequately shielded