CEN/CEN WS TeamUP

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Workshop: Procedures and thresholds in human decontamination in CBRN-E incidents

Human decontamination in CBRN-E incidents

Einführendes Element — Haupt-Element — Ergänzendes Element

Élément introductif — Élément central — Élément complémentaire

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CCMC will prepare and attach the official title page.

Contents

Page

Foreword

This CEN Workshop Agreement (CWA TeamUP:2026) has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid way to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop "Human decontamination in CBRN-E incidents", the secretariat of which is held by ÚNMZ consisting of representatives of interested parties on 2024-11-27, the constitution of which was supported by CEN following the public call for participation made on 2024-08-27. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CEN Workshop Agreement was provided to CEN for publication on YYYY-MM-DD.

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The following organizations and individuals developed and approved this CEN Workshop Agreement:

— name organization and individual

— name organization and individual

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[1] https://teamup-project.eu/

Introduction

The increasing instability of the global security landscape, coupled with the evolving nature of asymmetric threats, has significantly heightened the risk of incidents involving Chemical, Biological, Radiological, Nuclear, and Explosive (CBRN-E) materials. Such events, whether accidental or intentional, have the potential to cause mass casualties and widespread contamination, placing immense pressure on first responders and national emergency management systems. Within the complex cycle of CBRN-E response, the effective decontamination of exposed persons stands as a critical life-saving intervention. Its primary objectives are to remove or neutralize hazardous substances, prevent their further absorption into the body, and mitigate the pervasive risk of secondary contamination to medical personnel, facilities, and the wider community.

Historically, however, decontamination protocols have been characterized by significant shortcomings. They have often been rigid, procedurally focused, and lacking in clear, evidence-based endpoints for determining success. The operational goal has frequently been defined by ambiguous, subjective assessments such as being "as clean as possible," a standard that is neither scientifically rigorous nor legally defensible. This traditional approach prioritizes procedural compliance—the act of following a prescribed set of steps—over the verification of a successful outcome. This fundamental flaw has been exposed in numerous real-world crises. The Ebola epidemic in West Africa (2013–2016), for example, demonstrated that existing international guidelines for decontamination and personal protective equipment (PPE) were not always effective under the strenuous conditions of a large-scale biological event, leading to revisions by the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC). Similarly, the aftermath of the 1995 Tokyo subway sarin attack highlighted the devastating consequences of secondary contamination in hospital settings, a problem exacerbated by a lack of quantifiable clearance standards for victims. These events underscore a critical gap in existing standards: the absence of a validated, systematic framework specifically for the decontamination of human beings—both the victims of an incident and the first responders themselves.

This document provides the foundational framework for a CEN Workshop Agreement (CWA) that proposes a fundamental paradigm shift in the philosophy and practice of human decontamination. It moves away from a belief-based system, where success is assumed if a process is followed, to an empirical, evidence-based system, where success is proven against a scientifically defended standard. This new paradigm is built upon three core innovative pillars:

a) **Quantifiable Safety Thresholds:** The establishment of measurable, evidence-based limits for residual contamination on skin, providing a clear, defensible, and repeatable endpoint for the decontamination process.
b) **Advanced Competency Validation:** The implementation of a performance-based training and validation framework that uses high-fidelity simulation and objective evaluation to ensure responders can execute critical tasks flawlessly under duress.
c) **Data-Driven Continuous Improvement:** The creation of a systemic framework for digital documentation and auditing that transforms decontamination operations into a perpetually learning system, capable of analysing performance and institutionalizing improvements.

This shift from procedural adherence to verifiable outcomes has profound implications. It elevates the decontamination process from a rudimentary logistical task to a quasi-clinical, therapeutic intervention with a defined endpoint. It enhances legal defensibility and operational accountability, allowing an organization to prove it has met a standard of care. Most importantly, by integrating cutting-edge technology with modern principles of quality management, this framework aims to enhance the safety, efficiency, and interoperability of human decontamination operations, ultimately improving survival rates and bolstering societal resilience in the face of complex CBRN-E emergencies.

1 Scope

This CWA specifies procedures, validation methods, and quantifiable thresholds for the decontamination of persons exposed to CBRN-E agents during a crisis incident. It is intended for use by first responders, emergency planners, and public safety organizations to enhance operational effectiveness and international cooperation.

The document covers:

- Principles of human-centric decontamination.
- Protocols for setting up and managing decontamination zones.
- Specific procedures for chemical, biological, and radiological contaminants.
- A framework for establishing and verifying quantifiable safety thresholds.
- The integration of innovative technologies for real-time field detection.
- Advanced, scenario-based training methodologies for decontamination teams.
- Guidelines for digital documentation, auditing, and continuous improvement.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies.

EN 17173:2020 *European CBRN-E glossary*

3 Terms and definitions

For the purposes of this document, the following terms and definitions given in EN 17173:2020 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

[NOTE to the drafter: The Terms and definitions clause is compulsory. If there are no terms and definitions, add the following text: "No terms and definitions are listed in this document."]

3.1
CBRN-E
chemical, biological, radiological, nuclear, and explosive materials that can cause significant harm

[SOURCE: EN 17173:2020, definition 3.92, modified]

3.2

decontamination

process of making personnel, objects or areas safe by absorbing, destroying, neutralising, making harmless encapsulating, diminishing, or removing chemical or biological agents and radioactive material

Note 1 to entry: Decontamination can be passive or active, reflecting the urgency of the operational and/or tactical situation.

Note 2 to entry: In radioactive material decontamination includes administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility.

Note 3 to entry: Decontamination can be dry decontamination or wet decontamination.

[SOURCE: EN 17173:2020, definition 3.175]

3.3

first responder

certified member of an authority with responding first to the scene of an emergency

Note 1 to entry: First responders are members of fire and rescue departments, police departments, other law enforcement agencies, hazardous materials response teams, emergency medical services, workers, and other organizations that have public safety responsibilities and who would respond to rescue and treat victims, and who would protect the public during an incident.

EXAMPLE Frontline officer.

[SOURCE: EN 17173:2020, definition 3.280]

3.4

global catastrophic biological risk

GCBR

event where a biological agent could lead to a sudden, widespread catastrophe exceeding the collective capacity of governments and organizations to control it

3.5

human decontamination

decontamination procedures applied directly to the skin, hair, and clothing of a person

3.6

quantifiable threshold

specific, measurable limit of residual contamination on a surface (e.g., skin) below which the risk of adverse health effects is considered acceptable

3.7

secondary contamination

transfer of hazardous materials from one person or object to another, leading to the spread of contamination

4 The Human-Centric Imperative in Crisis Response

4.1 General

Effective human decontamination transcends a purely technical, assembly-line process; it requires a fundamental shift towards a human-centric approach that acknowledges and addresses the profound physiological, psychological, and social needs of individuals in crisis. The primary objective is to save lives and reduce suffering, and the decontamination procedure itself must be a therapeutic intervention rather than an additional trauma. This approach is built on a foundation of empathy, clear communication, and clinical prudence, ensuring that the response is as compassionate as it is effective. The "soft skills" often relegated to a secondary concern are, in fact, hard requirements for operational success. Research overwhelmingly demonstrates that psychologically-informed care directly improves key performance indicators such as public compliance with responder instructions, the speed and efficiency of the decontamination line, and overall public health outcomes.

4.2 The Principle of Primum Non Nocere (Do No Further Harm)

This foundational principle of medicine is paramount in decontamination. The process intended to help must not inadvertently cause additional injury or worsen a victim's condition. Responders must actively mitigate a range of potential harms:

a) **Physiological Harm:** Hypothermia is a common and serious threat, particularly for vulnerable populations such as children and the elderly, caused by prolonged exposure to water in cold conditions. The use of temperate water (ideally with a maximum temperature of 40°C or 104°F), minimizing exposure time in the shower, and providing immediate means for drying and re-warming are critical mitigation measures. Conversely, in hot environments, care must be taken to prevent heat-related illnesses. Chemical irritation or burns can result from using decontamination solutions that are too concentrated or incompatible with human skin, underscoring the importance of using mild soaps or validated decontaminants. Furthermore, mechanical injury from high-pressure water jets or abrasive scrubbing must be avoided. Damaged skin, including minor cuts and abrasions, can paradoxically increase the absorption of certain contaminants, turning a surface exposure into a more serious systemic one.

b) **Psychological Harm:** The experience of a CBRN-E incident is inherently terrifying. A poorly managed decontamination process—characterized by shouting, rough handling, a chaotic environment, and a lack of privacy—can compound this trauma, leading to long-term psychological distress, including Post-Traumatic Stress Disorder (PTSD). A calm, orderly, and respectful environment is crucial to minimizing this harm and fostering the cooperation necessary for an effective response.

4.3 Integration with Medical Triage

Decontamination is a critical life-saving measure, but it is not always the first priority. It must be seamlessly integrated with established medical triage protocols to ensure that the most critically injured receive immediate attention. The mantra "Life Over Limb, Limb Over Contamination" guides field decisions. A victim with a compromised airway, severe hemorrhage, or other immediately life-threatening injuries requires medical intervention before, or concurrent with, full decontamination. Responders must be trained and equipped to perform critical life-saving tasks while wearing appropriate PPE, using techniques to minimize self-contamination. For these priority-one casualties, clinical decontamination is performed in parallel with medical treatment, often in a designated area of a medical facility. Triage is not a singular event but a continuous process. Victims' conditions can change rapidly within the decontamination line. Therefore, all responders in the warm zone must be trained to recognize signs of medical distress—such as respiratory difficulty, seizures, or loss of consciousness—and to have a clear protocol for immediately alerting dedicated medical personnel.

4.4 Communication, Trust, and Compliance

In the chaos of an incident, clear, calm, and consistent communication is the most powerful tool for gaining the trust and cooperation of victims. Public compliance is not an automatic response to authority; it is a direct result of the perceived legitimacy of the responders and their actions. Fear, anxiety, and a perception of low control are powerful drivers of human behaviour in a crisis. A communication strategy that addresses these psychological factors is essential. Responders should project a calm and confident demeanour, providing simple, direct instructions in a clear voice. Explaining *what* is happening and *why* it is necessary can significantly reduce fear and anxiety. Evidence-based communication strategies include providing open and honest information about the incident, delivering health-focused explanations about the importance of decontamination, and giving sufficient practical information to guide victims through the process.

Communication must be adapted for a diverse population, overcoming barriers of language, culture, and disability. This includes the use of pre-recorded messages in multiple languages, universally understood pictograms, and simple hand gestures. The high ambient noise from pumps and generators necessitates the use of megaphones or visual aids to ensure instructions are received and understood. Ultimately, empathy and compassion are key; acknowledging victims' fear helps build the rapport needed to guide them through a difficult and frightening process.

4.5 Preservation of Dignity and Privacy

Losing one's clothing in front of strangers is a deeply vulnerable and humiliating experience. Protecting the dignity of victims is not a luxury; it is a critical component of a humane and effective response that fosters cooperation and minimizes psychological trauma. A failure to respect public needs for privacy and modesty can directly reduce compliance and cooperation. Practical measures must be integrated into the operational setup. Whenever possible, the decontamination process should be physically arranged to maximize privacy through the use of gender-separated corridors, opaque tents, and privacy screens. Modesty kits—containing towels, disposable gowns, blankets, and footwear—should be a standard part of the decontamination supply chain, provided to victims as soon as they exit the rinse station. Responders must be trained to handle this part of the process with professionalism and respect, avoiding any language or behaviour that could be perceived as judgmental or insensitive.

4.6 Adaptation for Vulnerable Populations

A "one-size-fits-all" approach to decontamination will invariably fail vulnerable individuals. Procedures must be flexible and adaptable to meet their unique physiological and psychological needs.

a) **Children:** Children may be separated from their parents and will likely be terrified. A designated responder trained in paediatric care can provide immense comfort. The ideal procedure allows a parent to accompany their child through the decontamination line. If a child is alone, a single responder should stay with them throughout the entire process to provide continuity of care and reassurance.

b) **Elderly and Individuals with Disabilities:** Standard ambulatory corridors may be impassable for those with mobility issues. Separate lines or dedicated procedures are required for individuals who use wheelchairs, walkers, or who are non-ambulatory. These individuals will require direct, hands-on assistance from responders to disrobe and wash.

c) **Service Animals:** Operational plans must include procedures for decontaminating service animals. These animals are not pets; they are essential for their handlers' independence and well-being, and separating them can cause significant distress and operational challenges.

5 A Systems-Based Framework for Decontamination Site Operations

5.1 General

A structured and meticulously planned operational framework is the backbone of any successful mass decontamination effort. Moving from the initial chaos of an incident to a controlled, effective process requires a systematic approach that integrates site layout, personnel management, and operational flow into a single, coherent system. This framework is not merely a logistical exercise; it is a critical safety system designed to protect victims and responders, prevent the uncontrolled spread of hazardous materials, and ensure a methodical and efficient decontamination process. By viewing the operation through a systems lens, it becomes possible to apply established principles from high-reliability organizations (HROs) and quality management, transforming the decontamination corridor from a simple "cleaning line" into a high-risk process manufacturing system designed to produce a "zero-defect" output—a decontaminated person—with maximum safety and efficiency. This approach aligns with international standards for crisis and incident management, such as ISO 22361 and ISO 22320, which emphasize structured processes, clear roles, and interoperability.

5.2 The Principle of Zonal Control

The fundamental principle for managing any hazardous materials incident is the establishment of strict contamination control zones. These zones create a gradient from the most contaminated area to a clean support area, preventing cross-contamination and ensuring responder safety. The demarcation between zones must be clear, using barrier tape, cones, or other visible markers, and access control points must be strictly enforced to maintain the integrity of the system.

a) **Hot Zone (Exclusion Zone):** This is the area of active contamination where the CBRN-E agent is present at its highest concentration. It is inherently dangerous, and entry is restricted to the minimum number of trained personnel required for life-saving rescues or initial hazard mitigation. All personnel entering the hot zone must wear the highest level of appropriate Personal Protective Equipment (PPE) to prevent exposure.

b) **Warm Zone (Contamination Reduction Zone):** This zone acts as a buffer between the hot and cold zones. Its primary function is to house the decontamination corridor, where systematic and thorough decontamination of all persons and equipment exiting the hot zone takes place. The level of contamination here is lower than in the hot zone but still poses a significant risk. Responders working in the warm zone must wear appropriate PPE, though it may be a level lower than that required for the hot zone, depending on the agent and environmental conditions.

c) **Cold Zone (Support Zone):** This is the "clean" area of the incident site, located upwind and uphill from the contaminated zones. It is intended to be completely free of contamination. The cold zone hosts the Incident Command Post, medical treatment and triage areas for decontaminated victims, logistical support, and rehabilitation areas for responders. No one is permitted to enter the cold zone from the warm zone without first being fully decontaminated and cleared through a verification and monitoring station.

5.3 Personnel Roles and Responsibilities

A successful decontamination operation relies on a team of responders where each member has a clear, predefined role and responsibility, operating within a formal Incident Command System (ICS) structure. This division of labor ensures efficiency and prevents confusion during a highstress event.

a) **Team Leader:** The operational and safety linchpin of the entire decontamination process. Reporting to the Incident Commander, this individual oversees the setup of the corridor, ensures all safety protocols are followed, manages personnel rotations to prevent fatigue, and serves as the primary decision-maker for the decontamination group.

b) **Communicators (Guides):** Positioned at the entrance of the corridor, these responders are the first point of contact for victims. Their role is critical for setting a calm and orderly tone. Using clear, simple language (often with megaphones and visual aids), they explain the decontamination process, provide instructions, and direct victims into the corridor, helping to manage fear and ensure an orderly flow.

c) **Assistants (Operators):** These are the hands-on responders inside the decontamination corridor. They physically assist victims who need help, such as the elderly, children, or those with injuries. They guide individuals through the disrobing, washing, and rinsing stations, ensuring the process is done thoroughly but compassionately, always with a focus on preserving dignity.

d) **Medical Monitors:** Stationed within or at the exit of the warm zone, these personnel are trained to spot signs of medical distress or toxic exposure. They provide immediate medical intervention if a victim's condition deteriorates within the corridor and conduct a secondary medical triage once victims have been decontaminated.

e) **Logistics and Supply Staff:** Working primarily in the cold zone, these individuals manage the critical supply chain. They ensure a continuous supply of water, decontamination solutions, fuel for pumps and heaters, replacement PPE for the response team, and modesty kits (towels, gowns, blankets, footwear) for the victims.

5.4 Systematic Process Flow

The decontamination corridor must be designed for a logical, linear, one-way flow to prevent recontamination. Each station in the corridor has a specific purpose, and victims should move smoothly from one to the next without backtracking.

a) **Entry & Instruction Point:** Victims are received from the hot zone. Communicators provide clear, concise instructions and reassurance. Initial gross decontamination (e.g., brushing off dry powders) may occur here before victims enter the corridor tents.
b) **Contaminated Clothing Removal (Disrobing):** This is arguably the single most effective step in decontamination, as removing clothing can eliminate 80-90% of contaminants.1 Victims are instructed to remove all clothing and jewellery and place them into designated, heavy-duty plastic bags, which are then sealed to contain the hazardous material. Separate areas for males and females must be established to preserve privacy.
c) **Wash Station:** Victims enter a showering area. The wash is conducted with a high volume, low-pressure stream of temperate water mixed with a mild soap or another appropriate decontamination solution. The focus is on gentle but thorough washing of the entire body, including hair and skin folds. The recommended duration is typically 5 to 15 minutes, depending on the agent.
d) **Rinse Station:** After the wash, a thorough rinse with clean, temperate water is essential to remove both the contaminant and the cleaning agent itself. This step helps prevent skin irritation from residual decontamination solutions. A minimum of 2–3 litres of water per person is recommended.
e) **Monitoring & Verification Point:** This is a critical innovation and a central control point in the system. Before exiting the warm zone, each victim is checked with appropriate detection equipment to verify that decontamination was effective. This could involve a radiological survey meter, a chemical agent detector, or a rapid biological screening test. If contamination is detected above the pre-defined threshold, the victim is sent back to the wash/rinse station for a second pass. This step provides an objective, auditable endpoint to the process.
f) **Drying & Redressing Area:** Once verified as clean, victims move to a dry, sheltered area. Here, they are provided with towels, blankets, disposable gowns, or replacement clothing to protect them from the elements and restore their sense of dignity.
g) **Exit to Cold Zone:** Cleared victims are directed out of the warm zone and into the cold zone, where they will undergo medical assessment, registration, and be provided with further support and shelter.

6 Agent-Specific Decontamination Protocols: An Evidence-Based Review

6.1 General

The efficacy of decontamination is critically dependent on tailoring procedures and agents to the specific nature of the CBRN hazard. A universal "one-size-fits-all" approach is insufficient and can be dangerous; responders must understand the scientific principles behind each agent type to apply the correct techniques safely and effectively. The choice of decontamination method involves a complex risk-benefit analysis that is agent- and context-dependent. For example, the "wash-in" effect, where water-based decontamination can paradoxically increase the skin penetration of certain chemicals, demonstrates how an intuitive action can be counterproductive if the underlying toxicology is not understood. This section provides the detailed scientific and medical rationale for distinct decontamination protocols.

6.2 Chemical Agent Decontamination

6.2.1 Principle

The primary goals are rapid physical removal and, where possible, neutralization of the agent. Many chemical warfare agents, such as nerve agents (e.g., Sarin, VX) and vesicants (blister agents like mustard gas), are readily absorbed through the skin and can cause systemic toxic effects within minutes. Therefore, speed is the most critical factor in mitigating injury and saving lives.

6.2.2 Procedure

a) **Immediate Gross Decontamination:** If visible liquid contamination is present, it must be addressed immediately. Using an absorbent material (e.g., pads, cloths, or specialized materials like the M291 resin kit), **blot** the liquid from the skin. It is crucial **not to rub or wipe**, as this action can spread the agent over a larger surface area and force it deeper into the skin's pores, increasing the absorbed dose. This initial "dry decontamination" step is vital for mitigating the "wash-in" effect associated with certain agents.

b) **Clothing Removal:** As with all agent types, this is the single most important step. Responders should instruct victims to remove all clothing and jewellery as quickly as possible. Clothing should be cut off rather than pulled over the head to avoid inhalation of trapped vapours. This step alone can remove 80-90% of the contaminant.

c) **Technical Decontamination (Wash/Rinse):** The universal standard for skin decontamination is a high-volume, low-pressure shower with mild liquid soap and temperate water. The surfactant action of soap helps lift the chemical agent from the skin so it can be washed away. However, for highly lipophilic (fat-soluble) agents like VX, some research indicates that surfactants and water hydration can increase the rate of skin penetration. This reinforces the importance of a thorough initial dry decontamination step to remove the bulk agent before wet washing. Abrasive washing or harsh scrubbing must be avoided, as this can damage the stratum corneum (the skin's outer protective layer), which ironically increases the rate of chemical absorption.

d) **Specialized Decontaminants:** Products such as the Reactive Skin Decontamination Lotion (RSDL) are highly effective but are typically reserved for trained responders due to cost and specific application procedures. RSDL contains components that both physically remove the agent and chemically neutralize it, offering superior performance against agents like VX compared to soap and water.

e) **Eye Flushing:** If the eyes have been exposed, they must be flushed immediately and continuously with saline solution or clean, potable water for at least 15 minutes, ensuring the runoff does not contaminate other parts of the face.

6.3 Biological Agent Decontamination

6.3.1 Principle

The goal is the inactivation and physical removal of pathogenic microorganisms (e.g., bacteria, viruses, spores) to prevent infection in the exposed individual and halt the chain of transmission through secondary contamination. Biological agents, such as the Ebola virus, can remain viable on surfaces for hours or even days, posing a significant secondary contamination risk.

6.3.2 Agents and Solutions

a) **For Human Skin:** The primary and most recommended method is a thorough wash with **mild soap and temperate water**. The mechanical action of washing, combined with the surfactant properties of soap, is highly effective at physically removing the vast majority of biological agents from the skin surface. Hand washing is a cornerstone of infection control.

b) **For Equipment and Surfaces:** For disinfecting PPE and equipment, more potent solutions are required. As recommended by the WHO and CDC during the Ebola crisis, a **0.5% sodium hypochlorite solution** (equivalent to a 1:10 dilution of typical household bleach, providing 5000 ppm active chlorine) with a minimum contact time of 10 minutes is a proven virucidal and bactericidal agent. Other effective agents include 0.5-3% hydrogen peroxide or glutaraldehyde-based preparations. These are generally **not safe for direct application to human skin** due to their corrosive nature.

6.3.3 Procedure

a) **Careful Clothing Removal:** Victims should remove all clothing carefully to minimize the aerosolization of particles. All items must be placed in clearly marked biological waste bags and sealed.

b) **Whole-Body Shower:** Instruct victims to take a thorough shower using soap and water. They should pay special attention to hair, underarms, fingernails, and skin folds where pathogens can accumulate.

c) **Thorough Rinse:** A complete rinse with clean water is necessary to wash away both the soap and any remaining microorganisms.

d) **Wastewater Management:** This is a critical control point. All water runoff from the decontamination corridor is considered infectious biological waste. It must be contained in bladders or a sump system and subsequently treated with a disinfectant (e.g., a higher concentration of bleach) before proper disposal according to hazardous waste regulations.

6.4 Radiological Agent Decontamination

6.4.1 Principle

Radioactivity cannot be "neutralized" or "inactivated." Radiological contaminants are physical particles (dust, liquids, aerosols) that emit ionizing radiation. Therefore, the principle of decontamination is the straightforward physical removal of these radioactive particles from the body's surface to stop ongoing exposure and prevent internal contamination through ingestion, inhalation, or absorption through wounds.

6.4.2 Procedure

a) **Clothing Removal:** Removing the outer layers of clothing is extremely effective and can eliminate up to 90% of radiological contaminants.

b) Initial Survey: Before washing, a trained responder should use a radiation survey meter (e.g., a Geiger counter with a pancake probe) to perform an initial scan of the victim. This helps identify the specific areas of highest contamination ("hot spots") and provides a baseline measurement to gauge the effectiveness of decontamination.

c) Gentle Washing:

- Instruct the victim to wash with mild soap and temperate water, using a soft cloth or sponge.
- It is vital to wash gently and avoid harsh scrubbing or the use of stiff brushes. Damaging the skin's integrity can allow radioactive particles to become embedded or absorbed, turning a surface contamination problem into a more dangerous internal one.
- Washing should proceed from cleaner areas toward more contaminated areas to avoid spreading the particles. Wounds should be cleaned first with care to prevent washing contaminants into them.

d) Hair Washing: If hair is contaminated, it should be washed with a gentle shampoo. The head should be tilted back so that the rinse water flows away from the face, minimizing the risk of swallowing or inhaling contaminated water.

e) Verification and Re-washing: After the initial wash and rinse, the victim must be resurveyed with the radiation meter. The goal is to reduce contamination to a level below the established threshold (e.g., < 0.1 Bq/cm^2). If hot spots remain, the gentle washing process should be repeated on those specific areas. If contamination persists, especially in or near a wound, the victim requires specialized medical evaluation and treatment.

7 Establishing Quantifiable Safety Thresholds

7.1 General

The most significant evolution proposed in this CWA is the transition from subjective, qualitative assessments to objective, quantifiable verification of decontamination efficacy. For decades, the endpoint of decontamination was defined by ambiguous phrases like "as clean as possible" or determined by simple visual inspection. This approach is inherently unreliable, lacks scientific rigor, and creates an unacceptable margin for error in life-and-death situations. This framework proposes a paradigm shift: the implementation of evidence-based, measurable safety thresholds for residual contamination on human skin. This innovation provides a clear, defensible, and repeatable endpoint for the decontamination process. By establishing a definitive "finish line," this framework enhances the safety of victims and responders, optimizes resource allocation, and introduces a level of accountability and transparency previously unattainable in field operations.

The three proposed thresholds, while numerically different, are philosophically consistent. They are each derived from the specific risk profile of the agent class: preventing deterministic effects for radiologicals, staying below a toxicological no-effect level for chemicals, and eliminating the risk of replication and infection for biologicals. This consistent, risk-based rationale makes the entire framework scientifically coherent and legally defensible.

7.2 Radiological Threshold: < 0.1 Bq/cm^2

7.2.1 Proposal

For radioactive contamination on skin, the proposed safety threshold is a residual activity of less than 0.1 becquerels per square centimeter (Bq/cm^2) above the natural background radiation level.

7.2.2 Justification

This threshold is derived from existing international standards, specifically ISO 8690:2024, which specifies methods to assess the ease of decontamination of surface materials.

While this standard is intended for inanimate surfaces, its application to human skin represents a highly conservative and health-protective choice. The rationale is grounded in established principles of radiation protection. According to guidance from the International Commission on Radiological Protection (ICRP), for very small areas of skin contamination ($< 1 \text{ cm}^2$), the risk of stochastic effects (e.g., cancer) is considered relatively unimportant, and dose limitations are dominated by the need to prevent deterministic effects (e.g., erythema, skin burns). The dose thresholds for these acute deterministic effects are very high, considerably exceeding 20 Gray (2,000 rad). A residual contamination level of $< 0.1 \text{ Bq/cm}^2$ is at the lower limit of what is reliably detectable by standard field survey instruments (e.g., a Geiger-Müller pancake probe). By setting the threshold at a level that is essentially "as low as detectable," it is ensured that any remaining dose to the individual is negligible and orders of magnitude below the level required to cause any deterministic harm.

7.3 Chemical Threshold: Derivation from Toxicological Data

7.3.1 Proposal

For chemical agents, the operational goal is the absence of any detectable agent using sensitive, field-calibrated equipment. This operational goal is benchmarked against a scientifically derived "Dermal Clearance Level" (DCL), which represents a level of non-concern for adverse health effects.

7.3.2 Justification and Methodology

Establishing a safe level for a chemical on the skin is more complex than for radiation due to vast differences in agent toxicity and skin absorption rates. This CWA proposes a novel, tiered methodology for deriving a DCL, adapting established principles from toxicological risk assessment used to determine a Derived No-Effect Level (DNEL).

a) **Identify Starting Point Data:**

   The process begins by identifying the most relevant toxicological dose descriptor for acute dermal exposure. The preferred starting point is a No-Observed-Adverse-Effect Level (NOAEL) from human or animal studies. If a NOAEL is unavailable, a Lowest-Observed-Adverse-Effect Level (LOAEL) is used. In the absence of either, the dermal Lethal Dose 50 (LD_{50})—the dose lethal to 50% of a test population—can be used as a conservative starting point. For example, the dermal LD_{50} for Sarin (GB) in a 70 kg human is approximately 1700 mg, while for VX it is as low as 10 mg, highlighting the vast difference in toxicity.

b) **Apply Assessment Factors (Safety Factors)**

   To account for uncertainties and to extrapolate from experimental data to a safe level for a diverse human population, a series of assessment factors (AFs) are applied. This is standard practice in toxicology. The cumulative AF is a product of individual factors, which may include:

   - Interspecies variation (e.g., AF=10 for extrapolating from animal to human).
   - Intraspecies variation (e.g., AF=10 to protect sensitive individuals in the human population).
   - LOAEL-to-NOAEL extrapolation (e.g., AF=10 if starting from a LOAEL).
   - LD_{50}-to-NOAEL extrapolation (e.g., AF=10-100 if starting from a lethal dose).
   - Duration of study (e.g., AF for sub-chronic to chronic extrapolation, less relevant for acute incidents).

A cumulative assessment factor of 100 to 1,000 is common in deriving healthprotective

limits from animal data.42

c) **Calculate the DCL**

The DCL is calculated by dividing the starting dose descriptor by the cumulative assessment factor. For example: $DCL = \frac{NOAEL}{AF_{inter} \times AF_{intra}}$. This calculation yields a defensible, health-protective value for the maximum acceptable total amount of residual agent on the skin (in mg or mg/kg), which can be converted to a concentration per unit area (e.g., mg/cm^2). This value then becomes the scientific benchmark that the detection limits of field verification equipment must be able to meet or exceed.

7.4 Biological Threshold: Non-Detection

7.4.1 Proposal

For pathogenic biological agents, the only acceptable safety threshold is the absence of detectable viable pathogens or their specific genetic material.

7.4.2 Justification

This absolute threshold is necessary because, unlike chemical or radiological contaminants, biological agents can replicate. A single viable bacterium or viral particle can multiply within a host, potentially causing a full-blown infection from an initial dose that would be harmless in a chemical or radiological context. Therefore, any detectable residual contamination poses an unacceptable risk of both primary infection to the victim and subsequent transmission to others. This "zero tolerance" approach is justified by established risk assessment principles:

a) **Quantitative Microbial Risk Assessment (QMRA)**

QMRA is a framework used to model the probability of infection from a given dose of a pathogen. The infectious dose for many pathogens can be very low, and it is often unknown for novel or weaponized agents.

For example, while the 50% infective dose (ID_{50}) for cutaneous anthrax is estimated to be in the thousands of spores for intact skin, this number is "considerably lower" if the skin is broken. Given these uncertainties and the high consequence of infection, the most prudent public health approach is to target a zero-dose endpoint.

b) **Analogy to Sterility Assurance Level (SAL):**

In the medical device and pharmaceutical industries, sterility is not defined as an absolute but as a probability. The Sterility Assurance Level (SAL) is the probability of a single viable microorganism occurring on an item after sterilization. A SAL of 10^{-6} (a one-in-a-million chance of a non-sterile item) is the standard for terminally sterilized medical products. While achieving a 10^{-6} SAL on human skin in the field is impossible, the underlying principle of reducing the probability of a viable organism to the lowest practicable level is directly applicable. For field decontamination, "non-detection" using the most sensitive available field technology (e.g., portable PCR) becomes the practical and defensible surrogate for achieving an acceptable risk level.

The following table summarizes the proposed quantifiable thresholds, their scientific basis, and the methods for their verification in the field.

Table 1 - Proposed quantifiable thresholds, their scientific basis, and the methods for their verification in the field

Contaminant Type	Proposed Threshold for Skin	Basis / Normative Reference & Rationale	Field Verification Method
Radioactive	$< 0.1 \text{Bq/cm}^2$ above background	Based on ISO 8690:2024. Highly conservative choice for skin, as ICRP guidance indicates deterministic effects have very high thresholds for small areas. Aims for As Low As Detectable.	Handheld alpha/beta/gamma contamination monitors (e.g., Geiger-Müller pancake probes).
Chemical	Non-detection by field equipment, benchmarked against a derived Dermal Clearance Level (DCL).	Derived from agent-specific dermal LD_{50}/NOAEL data using toxicological assessment factors (e.g., AF=100-1000) to establish a Level of Non-Concern.	Chemical Agent Monitors (CAMs), Ion-Mobility Spectrometers (IMS), portable GCMS, or Raman Spectrometers with detection limits below the DCL.
Biological	Absence of detectable viable pathogens or genetic material.	Based on principles of Quantitative Microbial Risk Assessment (QMRA) and Sterility Assurance Level (SAL). Due to replication potential, any viable organism is an unacceptable risk.	Rapid immunological tests (Lateral Flow Assays), field-portable PCR units for genetic material, or ATP bioluminescence assays for general biological residue.

8 Technology-Enabled Verification and Competency

8.1 General

The innovative proposals of this CWA—quantifiable thresholds and validated competency—are not merely theoretical constructs. They are made practical and achievable through the deliberate integration of existing and emerging technologies for both operational verification and personnel training. This creates a symbiotic relationship: the demand for verifiable outcomes drives the need for better field technologies, while the availability of these advanced tools makes the implementation of a more rigorous standard operationally feasible. This framework is not just a document; it is an engine for capability development, incentivizing investment in better technology and training systems to pull the entire field of CBRN-E response forward.

8.2 Real-Time Field Verification Technologies

The implementation of quantifiable thresholds is only possible through the integration of modern, field-deployable detection technologies. These tools move verification out of the distant laboratory and into the hands of responders, enabling real-time decision-making at the incident site. The following table provides a summary of key technologies and their capabilities in relation to the proposed thresholds.

Table 2 - Summary of key technologies and their capabilities in relation to the proposed thresholds

Technology	Type	Examples Target Agent(s) Typical Detection Limit	Suitability for Threshold	Verification
Ion-Mobility Spectrometry (IMS)	Smiths Detection SABRE 4000, Bruker RAIDM100plus	Nerve Agents (G, V), some TICs	$0.005–0.5 \text{mg/m}^3$ (vapor)	Excellent for screening for nerve agent presence at levels relevant to health risk.
Handheld Raman Spectrometry	Thermo Fisher FirstDefender, Pendar X10	Broad Chemical Library (CWA, TICs, Narcotics)	Compound-dependent; typically % to high ppm. SERS enhances to low ppm/ppb.	Good for specific identification of bulk contaminants; SERS required for trace-level verification.
Portable GC-MS	908 Devices MX908	Broad Chemical Library	Nanogram / ppb level	Gold standard for sensitive, specific verification in the field. Directly supports DCL verification.
Lateral Flow Immunoassay (LFA)	Field test strips	Specific biological agents (e.g., B. anthracis, Ricin)	$\sim10^5-10^6 \text{ CFU/mL}$	Excellent for rapid, qualitative (Yes/No) field screening.
Field-Portable PCR	"Lab-on-a-chip" systems	Specific biological agents (DNA/RNA based)	$< 10-100$ spores/cells	Gold standard for sensitive, specific verification. Directly supports "non-detection" threshold.
Geiger-Müller (GM) Probe	Pancake probes	Alpha, Beta, Gamma radiation	$\sim0.1 \text{Bq/cm}^2$	Standard, proven technology for directly verifying the radiological threshold.

a) **Chemical Detection:** Portable devices now offer laboratory-grade sensitivity in a ruggedized, handheld form. Ion-Mobility Spectrometers (IMS) can detect toxic chemical vapors down to parts-per-billion (ppb) concentrations, providing an immediate "all clear" or "re-decontaminate" signal. Handheld Raman spectrometers and portable Gas Chromatography-Mass Spectrometry (GC-MS) units allow for highly specific identification of unknown substances, even at trace levels, and can be used to verify that decontamination was successful.

b) **Biological Detection:** The days of waiting hours or days for lab results are over. Modern biological detection platforms provide answers in minutes. Immunochromatographic assays (LFAs), similar to a home pregnancy test, can detect specific antigens for agents like Bacillus anthracis (anthrax) or Ebola virus within 15-30 minutes. The CDC has specifically validated rapid antigen tests for Ebola for field use. For definitive confirmation, "lab-on-a-chip" PCR tests provide highly sensitive and specific genetic confirmation of a pathogen's presence, bridging the gap between field screening and laboratory accuracy.

c) **Radiological Detection:** Digital dosimeters and contamination probes provide instant, easy-to-read digital outputs of radiation levels, eliminating the ambiguity of older analogue devices. They can automatically log data, timestamp measurements, and create a digital record for each individual, forming a crucial part of the audit trail discussed in Section 6.

8.3 Advanced Training Methodologies and Competency Validation

Effective protocols are rendered useless if personnel cannot execute them flawlessly under the immense physiological and psychological pressure of a CBRN-E incident. This CWA advocates for a fundamental shift away from traditional, knowledge-based instruction towards a dynamic framework of performance-based training and competency validation.

a) **High-Fidelity Simulation:** Training must move beyond the sterile classroom and into environments that replicate the chaotic and stressful conditions of a real event. Drills should be conducted under simulated adverse conditions—such as low light, extreme temperatures, and high levels of ambient noise—to induce stress inoculation and mitigate performance degradation. The use of professional role-players trained to portray a wide spectrum of victim behaviours (panicked, uncooperative, unconscious) is essential for practicing not only technical procedures but also critical communication and deescalation skills. All performance-based training must be conducted while wearing the complete PPE ensemble to acclimatize responders to the significant physical and psychological burdens of the gear.

b) **Training Technologies:** Innovation in training is driven by technologies that allow for safer, more scalable, and more analytical learning experiences.

   1) **Fluorescent Markers:** For validating technique, harmless UV-fluorescent surrogates are an invaluable tool. A surrogate can be applied to a training mannequin or a responder in a protective suit to simulate contamination. After a decontamination drill, an instructor uses a UV light to instantly reveal any remaining "hot spots" that were missed, providing immediate, powerful visual feedback.

   2) **Virtual and Augmented Reality (VR/AR):** VR platforms offer a revolutionary tool, allowing responders to be immersed in complex, hazardous, and large-scale scenarios without the associated cost, logistics, or safety risks of a physical exercise. VR is ideal for practicing initial decision-making and command-and-control functions. AR overlays can enhance physical drills by projecting simulated contamination or procedural prompts onto the real-world environment.

c) **Objective Structured Performance Evaluation (OSPE):** Competency cannot be assumed; it must be formally and rigorously validated. The OSPE, a standardized practical examination adapted from medical education, is the proposed gold standard. Using detailed, evidence-based checklists modelled on those developed by the CDC for high-risk pathogen response, qualified evaluators must observe and verify every critical step of a procedure. This is not a graded test but a binary validation: a trainee must demonstrate 100% proficiency on all safety-critical steps to be certified as competent. Any failure on a critical step requires immediate corrective feedback, re-training, and re-evaluation. These checklists, drawn from military and civilian best practices, provide a clear and objective measure of skill mastery.

9 A Framework for Systemic Learning and Continuous Improvement

9.1 General

The efficacy of human decontamination operations cannot be assured solely by the quality of its protocols; it requires a robust, integrated framework for data capture, performance analysis, and systemic evolution. This section delineates an innovative approach that treats documentation not as a passive, post-facto requirement, but as the central nervous system of a dynamic, data driven operation. The objective is to move beyond mere compliance and establish a culture of continuous improvement, legal defensibility, and organizational learning. This framework creates an organizational "memory" and a mechanism for learning, transforming one-off "lessons learned"—which are often forgotten—into institutionalized, systemic improvements. By capturing objective, quantitative data, the system allows for statistical analysis to identify systemic weaknesses and drive evidence-based change, embodying the principles of a High-Reliability Organization (HRO).

9.2 The Principle of Evidentiary-Quality Digital Record-Keeping

The transition from analogue, paper-based records to a comprehensive digital system is a foundational requirement for modern decontamination operations. Paper records are inherently prone to error, loss, illegibility under field conditions, and are incapable of supporting real-time analysis. A digital framework provides data integrity, non-repudiation, and the capacity for large-scale analytics.

At the core of this system is the Individual Decontamination Record (IDR), a unique digital log created for every person—victim or responder—who undergoes the decontamination process. This record provides the concrete specifications for the digital system, moving the concept from an abstract idea to a defined data architecture essential for implementation.

Table 3 – Structure of the Individual Decontamination Record (IDR)

Data Category	Data Field	Description & Rationale
Identification	Unique ID (e.g., QR Code)	Primary key for all data. Ensures non-repudiation and links all records to a single individual.
	Triage Category (Initial)	Links decontamination priority to medical priority. Essential for operational planning.
Chronometrics	Timestamp - Entry to Warm Zone	Marks the start of the process. Critical for overall throughput analysis.
	Timestamp - Exit from each Station	Granular data to identify specific process bottlenecks (e.g., delays at disrobing).
	Timestamp – Exit to Cold Zone	Marks the end of the process. Provides total processing time per individual.
Procedural Data	Suspected/Confirmed Agent(s)	Informs risk assessment and ensures correct protocols and verification methods are used.
	Decontamination Solution Applied	Documents the specific intervention. Allows for efficacy analysis of different solutions.
	Number of Decon Cycles	Records if an individual required re-washing, indicating a potential process failure.
Efficacy Data	Initial Contamination Reading (Value & Unit)	Establishes the baseline challenge. Data should be auto populated from the detector if possible.
	Final Contamination Reading (Value & Unit)	Provides objective, quantitative evidence that the threshold was met. The core of the audit trail.
Attribution	Verification Operator ID	Assigns accountability for the final "clear" decision.
	Assisting Operator(s) ID	Documents personnel involved in the process for performance tracking and analysis.

The strategic value of the IDR is maximized when it is integrated into the broader incident management ecosystem. Using standardized data exchange protocols, the decontamination data stream should be fused with other platforms, such as digital patient tracking systems. Lessons from mass casualty incidents like the Boston Marathon bombing highlighted challenges in comprehensive patient tracking, underscoring the need for robust, interoperable digital systems. This integration provides incident command with a live, comprehensive Common Operational Picture (COP), enabling superior situational awareness and informed, real-time strategic decision-making.

9.3 Multi-Modal Auditing and Performance Analytics

The resulting repository of high-integrity data creates a powerful and immutable audit trail, enabling multi-faceted analysis that supports both real-time operations and long-term strategic improvement.

a) **Real-Time Operational Intelligence:** During an active incident, data can be visualized on dashboards, allowing commanders to monitor key performance indicators (KPIs) such as average processing time per person, clearance success rates on the first pass, and resource utilization. This allows for syn-action adjustments, such as reallocating personnel to alleviate a bottleneck identified through live timestamp analysis.

b) **Post-Hoc Process and Efficacy Analysis:** Following an incident or drill, the complete dataset can be subjected to sophisticated analysis. Techniques like process mining can be used to visualize the actual flow of individuals through the corridor, revealing deviations from protocol and hidden inefficiencies. Statistical analysis can correlate decontamination protocols with efficacy data to empirically determine the most effective methods for specific agents.

c) **Forensic and Administrative Review:** The evidentiary-quality log provides an objective, verifiable record of all actions taken. In the event of legal or administrative review, this data furnishes irrefutable evidence of due diligence and adherence to established standards of care, providing a robust defense against claims of negligence.

9.4 Institutionalizing a Continuous Improvement Cycle

The ultimate purpose of this data-centric framework is to create a self-correcting system that learns from every experience, whether real or simulated. This principle of continuous improvement is essential for maintaining an adaptive and resilient response capability in the face of evolving threats.

a) **The Data-to-Training Feedback Loop:** The insights gained from performance audits must be systematically fed back into the training and competency validation framework described in Section 5. For example, if analysis reveals a persistent failure to decontaminate a specific body area across multiple teams, this finding should trigger an immediate review of the training curriculum and the corresponding OSPE checklists to address this identified gap.

b) **Adopting Formal Improvement Methodologies:** To structure this process, organizations should adopt a formal quality improvement model, such as the DMAIC (Define, Measure, Analyze, Improve, Control) cycle from Six Sigma. This provides a rigorous, data-driven methodology for identifying the root causes of performance issues, developing and testing solutions, and implementing controls to sustain the improvements. The application of DMAIC and similar Lean Six Sigma methodologies has proven effective in improving efficiency and reducing errors in emergency medical services and hospital emergency departments, demonstrating its direct applicability to the high-stakes environment of a decontamination line. This systematic approach ensures that "lessons learned" are translated into tangible, lasting enhancements to protocols, technologies, and personnel training.

10 Conclusion

The framework articulated within this document represents more than an incremental update to existing procedures; it signifies a fundamental paradigm shift in the philosophy and practice of human decontamination following a CBRN-E incident. For too long, the approach has been predicated on procedural compliance rather than on verifiable outcomes, relying on subjective assessments of "cleanliness" that offer little assurance to victims, responders, or commanders. This document challenges that legacy by establishing a new foundation for decontamination — one that is empirical, data-driven, human-centric, and geared towards creating a perpetually learning response system. By holistically integrating three core innovative pillars—quantifiable safety thresholds, advanced competency-based training, and a systemic framework for data driven improvement—this CWA provides a comprehensive blueprint for building a more effective, accountable, and resilient CBRN-E response capability for the 21st century.

The first and most critical innovation is the establishment of quantifiable, evidence-based thresholds for determining the successful endpoint of decontamination. This move away from the ambiguous and legally precarious "as clean as possible" standard introduces a level of scientific rigor and objectivity previously absent from field operations. By defining a specific, measurable limit of residual contamination below which risk is deemed acceptable, this framework provides an unambiguous operational goal. For the victim, it offers tangible, data backed assurance of their safety, a critical factor in mitigating psychological trauma. For the responder, it transforms a high-stakes judgment call into a verifiable procedural step, reducing cognitive load and improving decision-making under duress. For the incident command structure, it provides a legally defensible and auditable record of due diligence, demonstrating that a scientifically validated standard of care was met. This single innovation elevates the entire process from a rudimentary washing exercise to a precise, quasi-clinical intervention with a defined therapeutic endpoint.

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