

**PRIMARY RESPONSE INCIDENT
SCENE MANAGEMENT (PRISM)
GUIDANCE for CHEMICAL
INCIDENTS**



**VOLUME 1: STRATEGIC GUIDANCE FOR
MASS CASUALTY DISROBE AND
DECONTAMINATION**

Edited by R.P. Chilcott & R. Amlôt

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PRISM GUIDANCE FOR CHEMICAL INCIDENTS

VOLUME 1

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Foreword

The Primary Response Incident Scene Management (PRISM) series was written to provide authoritative, evidence-based guidance on mass casualty disrobe and decontamination during a chemical incident. The PRISM documentation comprises three volumes:

Volume 1: Strategic Guidance

Presents a review of best practices, collates available evidence and identifies areas that require further investigation. The document is relevant to senior incident responders (e.g. Chief Officers) and those responsible for emergency planning and civil contingencies, as it describes the supporting technical information which underpins the rationale for each stage of disrobe and decontamination and highlights potential challenges.

Volume 2: Tactical Guidance

The second volume provides an overview of the processes involved in mass casualty disrobe and decontamination and the rationale which underpins each process. The document does not include supporting technical information or potential challenges. Volume 2 has particular application in the training and exercising of first responders and officials involved with domestic preparedness and emergency management.

Volume 3: Operational Guidance

The salient features of mass casualty disrobe and decontamination are presented in Volume 3. The purpose of Volume 3 is to provide all Federal, State or Tribal first responders with a simple and readily accessible guide to the critical aspects of the initial incident response process.

The underpinning basis of the PRISM guidance documentation is scientific evidence accrued from a recent program of research sponsored by the Biomedical Advanced Research Development Agency (BARDA), the aim of which was to ensure that all casualties exposed to potentially hazardous chemicals receive the most effective treatment possible during the initial stages of an incident.

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Introduction

The purpose of this document is to provide evidence-based guidance on best practice during the initial response phase of an incident involving potential exposure of civilians to hazardous chemicals. The initial response can be divided into six main elements:

Evacuation

Prompt, orderly movement away from hazardous areas is a key component of the initial response. Inappropriate or delayed evacuation may exacerbate exposure to hazardous chemicals and may have an adverse effect on subsequent operations.

Disrobe

The effectiveness of rapidly removing contaminated clothing in a safe manner cannot be overemphasized and is a process that requires good communication to facilitate casualty compliance.

Decontamination

Whilst disrobe will remove the vast majority of contamination, exposed areas will require decontamination to remove hazardous chemicals from the skin and hair. The process of decontamination can be divided into three forms; improvised, gross and technical. Improvised decontamination is the immediate removal of contamination using any available means and can be divided into “dry” and “wet”. Dry improvised decontamination is performed by blotting exposed skin and hair with any available absorbent material and should be the *default option* for improvised decontamination. Wet improvised decontamination should only be used when the contaminant is caustic (e.g. provokes immediate skin irritation) or particulate in nature. Gross decontamination involves the “ladder pipe system” whereby two fire pumps are used to produce a corridor through which casualties may be sprayed with large volumes of water mist. Technical (or “thorough”) decontamination requires the use of bespoke decontamination units and associated resources that need to be transported to and deployed at the scene of an incident. The delayed availability of technical decontamination is compensated for by the use of improvised and gross decontamination.

Active drying

The act of drying the skin after showering is a key step in removing contaminants from the skin surface. It is important that this simple but effective process is performed in an appropriate manner to prevent any further spread of contamination.

Communication and casualty management

Good communication is key to acquiring the trust and cooperation of casualties and will maximize the overall efficiency of the initial response phase. Failure to adequately interact with casualties may lead to unnecessary anxiety, non-compliance and security issues at the scene of an incident.

Special requirements (identifying and decontaminating vulnerable and at-risk casualties)

Casualties may be unable to comply with instructions issued by emergency responders due to mental impairment, physical disability or simply an inability to understand the spoken language. In order to maintain operational efficiency, casualties who are unable to comply with instructions will need to be rapidly identified and provided with appropriate assistance.

The six process elements are summarized in Figure 1. The incident recognition and post-initial response phases are outside the scope of this guidance document.

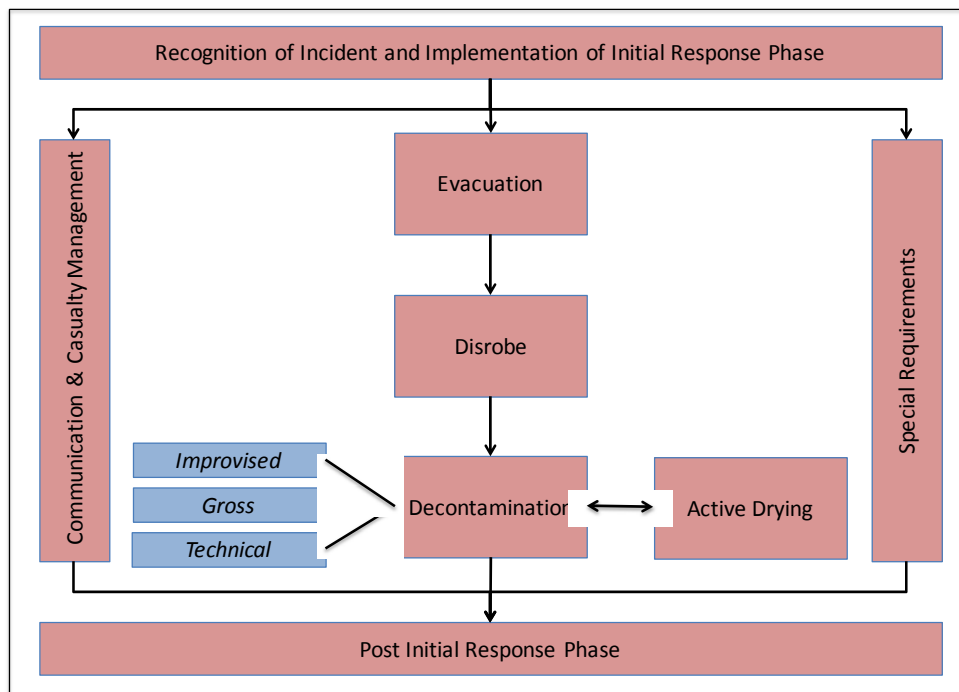


Figure 1: Constituent elements of the initial response phase. Note that the default method for improvised decontamination should be dry decontamination.

The operational guidance provided in this document is based on existing best practice and scientific evidence. Each response element has been critically evaluated in terms of current practices, prior evidence and new evidence, with knowledge gaps or uncertainties highlighted to facilitate an objective assessment of the corresponding recommendations. The most recent evidence was acquired from laboratory studies and field trials conducted as part of the Advanced Studies of Mass Decontamination (ASoMD) project [1-13].

Prior evidence was identified from a literature search using the ISI Web of Knowledge™ and PsycINFO™ databases. Search terms were: “mass decontamination”, “ladder-pipe system”, “disrobing” and “CBRN”. Internet search engines (“Google” & “Google Scholar”) were used to ensure that no further articles had been missed in the electronic database search. In addition to publications in scientific journals, ten guidance documents were identified which met the search criteria (Table 1):

Institution	Reference
Department for Communities and Local Government	[14]
Edgewood Chemical Biological Center	[15]
Harvard School of Public Health	[16]
Health Protection Agency	[17]
Home Office	[18]
National Ambulance Resilience Unit	[19]
National Health Service	[20]
National Health Service Scotland	[21]
US Army Chemical, Biological, Radiological and Nuclear School	[22]
US Department of Homeland Security	[23]

Table 1: Mass casualty guidance documentation identified from literature search, reported by institution.

Review and Assessment of Initial Response Processes

A. Evacuation

i. Current Practice

The initial action of emergency responders to any chemical incident should be to move casualties away from the immediate contamination hazard. This may involve self-evacuation on the part of those who are still able to freely move, or assisted evacuation through snatch-rescues by appropriately protected emergency services personnel. Most current guidance documents explicitly mention evacuation from the “hot zone” (or sometimes “red zone”) to the “warm zone” (or “white zone”) as an integral part of the decontamination process [14, 15, 18, 19, 21-23]. The need to evacuate upwind and uphill from the hot zone is mentioned in some [18, 19, 23]. Some guidance documents recommend that responders do not attempt to enter the hot zone to assist in the evacuation unless they are using appropriate PPE [14, 23]. The issue of self-evacuation, whereby casualties leave the scene of an incident of their own accord, has been identified as a potential health risk to the wider community and healthcare facilities due to the potential for uncontrolled spreading of contamination [23].

ii. Prior Evidence

Evacuation to a place of relative safety is a well-established initial step to protect casualties during chemical incidents [24]. In one confirmatory study, Preston et al. [25] drew on data from the Hazardous Substances Emergency Events Surveillance (HSEES) database to test the effect of evacuation on the amelioration of health effects associated with exposure to hazardous chemicals. They found that in 7.7% (of 2,930) incidents where evacuation occurred, there was a significantly lower number of adverse health effects within 24 hours of the incident, compared to incidents in which no evacuation had been implemented. It should be noted that this reduced risk was only found when the chemical was acid, ammonia, or chlorine.

iii. New Evidence

Historically, the clinical treatment of casualties has been performed following evacuation and decontamination [24, 26]. The arrival of specialist assets to the scene would likely cause a delay in evacuation and decontamination and may consequently reduce the survivability of a hazardous chemical incident, especially for non-ambulant, high-priority patients. As such, several countries have developed a capability to allow advanced clinical care within hot zone environments. In the US for example, responders can draw upon civil support teams, DoD assets and specialized urban/regional HazMat teams. In other countries such as the UK, the ambulance services can deploy a Hazardous Area Response Team (HART) or Special Operations Response Team (SORT) to perform potentially life-saving procedures such as endotracheal intubation, intra-osseous antidote administration and hemostatic interventions.

Recent studies that have sought to identify effective communication strategies for decontamination during hazardous chemical release incidents [27, 28] can also be applied to the management of evacuation. Health-focused, open, frequent and practical instructions could help facilitate evacuation (see Section G for further details).

iv. Knowledge Gaps or Uncertainties.

Such an apparently simple step as evacuation can present a number of practical problems due to inherent uncertainties regarding the source, location and magnitude of the contaminant and environmental factors such as changes in wind direction. Any difficulty in establishing a safe distance from the point of release should lead to consideration of alternative tactics, such as advising “shelter in place”. Such issues may be location-specific and so only resolvable at the time of an incident. There is also a lack of detailed guidance on evacuation protocols for terrorist incidents, e.g. the minimum safe distance from the hot zone, although evacuation guidance exists for more generic (transport-related) incidents [29]. This may be due to situational factors and the nature of the contaminant [23, 24]. As such, further work is required to confirm the necessary size of the hot zone and the distance required for effective evacuation according to different scenarios.

Non-ambulant casualties may arise through traumatic injury related to the incident or a pre-existing disability. Life-threatening injuries may necessitate stabilization of the patient prior to movement. However, evacuation would be a priority over stabilization if the hot zone were overtly life-threatening [24]. The evacuation of non-ambulant casualties from the hot zone may require a “snatch rescue” [30] in advance of the arrival of specialist resources for which appropriate protective equipment would be required to prevent the rescuer from becoming a casualty. In the presence of an airborne hazard, it would be inappropriate for a responder to attempt a snatch rescue without some level of respiratory protection. As the primary role of the emergency services is to save lives, this could pose a considerable

dilemma, especially where non-ambulant hot-zone casualties are visibly distressed. Overall, there is a need for further work to investigate the effect of evacuation from the hot zone on health risk reduction/prevention for both casualties and emergency responders.

- **Casualties should be evacuated from the scene of a hazardous chemical release as soon as possible.**
- **Responders should direct casualties to self-evacuate if possible.**
- **Only trained responders wearing appropriate protective equipment should enter the hot zone to assist evacuation.**
- **The warm zone should ideally be uphill and upwind from the hot zone. The distance between the warm zone and the hot zone should be as long as possible without incurring a delay of more than 5 minutes to the decontamination process.**
- **Where evacuation is not possible, people remaining in the hot zone should be encouraged to take shelter, close doors and windows, and keep themselves as far removed from the contaminant as possible.**
- **Whether instructing casualties to evacuate or to shelter in place, it is vital that emergency responders use an effective communication strategy, whereby the importance of the action is explained to the casualty in terms of their health.**
- **Responders should also adopt an effective communication strategy to explain to casualties why self-evacuation may be harmful and to discourage casualties from leaving the hot zone without undergoing decontamination.**

B. Disrobe

i. *Current Practice*

Disrobing is an essential part of the decontamination process and should be carried out at the earliest possible opportunity. This recommendation is reflected in all of the guidance documents reviewed [14-23]. However, only two specify a time frame, stating that the maximum benefit will be achieved if disrobing is carried out *within 15 minutes* of exposure [18, 19]. While a number of guidance documents explicitly state that clothing should be removed prior to undergoing decontamination [16, 17, 21-23], notably two documents [15, 19] state that if clothing is difficult to remove, or casualties are unwilling to disrobe, decontamination can be carried out without casualties undressing. This issue is returned to in the 'New Evidence' section below.

Reducing the delay between initial exposure to a contaminant and subsequent emergency response actions is considered one of the most important factors for determining the number of lives saved. Current guidance highlights the need for rapid disrobing, suggesting that disrobing should occur: 'as soon as possible' [20]; 'within minutes of exposure' [16], and 'immediately' [15]. A time window for disrobe is rarely specified; where it does appear, it has been suggested that disrobing should take place within 15 minutes of exposure [18, 19].

Current guidance differs widely in the level of detail provided on disrobing. Most guidance simply states that disrobing should be carried out as a priority [16-18, 20, 21, 23], without providing detailed guidance on *how* disrobing should be carried out. Only one document identified provides substantial detail about optimum disrobing procedures [15], stating that, where possible, clothing should be cut off, rather than lifted over the head. If clothing cannot be cut off and must be lifted over the head, the casualty should use their hands to pull the clothing away from their face while lifting the item over their head. This approach will prevent potentially contaminated clothing from coming into contact with the casualty's eyes, nose, or mouth during the disrobing process.

Privacy concerns should be taken into account when asking casualties to disrobe, as well as during the decontamination process as a whole. Of seven guidance documents identified that consider the issue of privacy, only two documents suggest that privacy is important for facilitating the smooth-running of the decontamination process [16, 23], although five documents suggest that privacy should be considered when practical [15, 17-19, 21]. On the whole, privacy and dignity is usually only briefly considered within current guidance, and only two documents recognize that failure to protect public privacy may result in reduced public compliance with decontamination [16, 23].

ii. *Prior Evidence*

Several studies have confirmed that clothing can absorb and retain chemicals and so disrobing at the earliest possible opportunity would be most beneficial to casualties [31-33]. For example, Matar et al. [33] assessed the percutaneous absorption of sulfur mustard, VX, soman and methyl salicylate through bare and multi-layered clothed skin, where clothing was removed at different time intervals. These studies indicated that the rapid removal of contaminated clothing can limit the effects of percutaneous absorption; however, the level of protection provided by clothes against toxic chemicals decreases rapidly with time. Feldman [31] studied a variety of types of civilian clothing exposed to the sulfur mustard simulant, methyl salicylate, in vapor form: clothing continued to off-gas more than 40 minutes after exposure. Similar work carried out by Gaskin et al. [32, 34] confirmed that clothing does continue to off-gas following contamination with a range of chemicals and that heavy or wet clothing is most likely to present an off-gassing hazard. These studies indicate that casualties and responders are potentially at risk from secondary contamination if clothing is not removed and isolated rapidly. This risk was demonstrated after the sarin attack on the Tokyo subway system in 1995, where thirteen of the fifteen physicians who treated patients in a Tokyo emergency department experienced symptoms of sarin exposure due to off-gassing of contaminated casualties and their clothing [35].

Rapid disrobing is therefore necessary both to limit the amount of contaminant which is transferred through clothing onto casualties' skin and to prevent secondary contamination of emergency responders and healthcare workers due to off-gassing. However, casualties may be unwilling to disrobe due to privacy concerns.

Evidence from real incidents has shown that affected casualties exhibit significant dissatisfaction with the decontamination process if they did not feel they were given sufficient privacy. A decontamination incident in 1999 in Central Valley, California left female casualties feeling "humiliated" due to disrobing in front of at least 100 emergency personnel, television crews and spectators. One female casualty described how her underwear was pulled off by a paramedic against her will, whilst another female casualty stated that the process "felt like rape" [36, 37]. Additionally, in a suspected chemical incident at B'nai B'rith Headquarters in Washington DC in 1997, some police officers initially refused to go through the decontamination process due to the live broadcasting of the incident scene from news cameras on top of a nearby building [38]. Recent evidence from a series of linked studies have shown that those who report low levels of privacy during the decontamination process also report being less likely to comply with the need for decontamination during a real incident [27, 28, 39].

Despite the evidence that privacy is essential to ensure the smooth-running of the decontamination process, few guidance documents currently recognize that failure to provide casualties with sufficient privacy may result in reduced compliance with

decontamination [16, 23]. While privacy is not directly related to a casualties' medical outcome, lack of privacy may reduce compliance with disrobe and decontamination procedures and so may result in delays to the response process.

Two guidance documents suggest that if casualties are unwilling to disrobe due to issues of privacy and modesty, they may be allowed to go through the decontamination process while still clothed [15, 19]. Allowing casualties to progress through decontamination while still clothed may reduce privacy and modesty issues and speed up the decontamination process. However, undergoing decontamination whilst clothed could enhance transfer of chemicals onto the skin surface during showering, placing casualties at increased risk (Figure 2). The risk of enhanced skin contamination caused by decontamination whilst clothed should be clearly communicated to casualties.

Emergency responders should seek to provide sufficient privacy for casualties, without compromising the effectiveness of the decontamination process. Methods of protecting casualties' privacy include: providing casualties with disrobe and re-robe suits; ensuring that decontamination is conducted out of sight of passers' by or the media. Effective communication is also essential to ensure that casualties understand the importance of disrobing and decontamination and do not perceive responders to be behaving in an illegitimate way (see Section G).

A: Disrobe followed by showering



B: Shower without disrobe



Figure 2: Photographs of residual skin contamination (indicated by green areas) on torso of volunteer following water shower decontamination. Removal of clothing before showering results in efficient removal of contaminant (A). In contrast, there is an increased spread and intensity of residual skin surface contamination when contaminated clothing is worn during showering (B).

iii. *New Evidence*

Recent studies have sought to understand the consequences of failing to disrobe prior to gross decontamination [2, 3, 7, 8, 10, 12], as emergency responders may permit clothed casualties to undergo decontamination as a pragmatic option if casualties are unwilling or unable to disrobe. The studies confirmed that clothing can initially provide a protective barrier to external contaminants. Additionally, disrobing is an effective strategy for mitigating exposure in the absence of showering. Most importantly, the studies clearly demonstrated that there may be significant transfer of contaminant from clothing to the skin surface if decontamination is performed on clothed casualties. Consequently, it is considered critical to perform disrobe prior to decontamination.

iv. *Knowledge Gaps or Uncertainties*

The importance and effectiveness of disrobing can be considered to be unequivocal. The potential for decontamination showering to increase exposure to a contaminant in clothed casualties emphasizes the importance of disrobing *prior to* decontamination showering in the early stages of a chemical incident. Disrobing is at least an order of magnitude more effective than decontamination in reducing exposure to chemical contaminants, but must be conducted within minutes of exposure for optimum effectiveness (Figure 3).

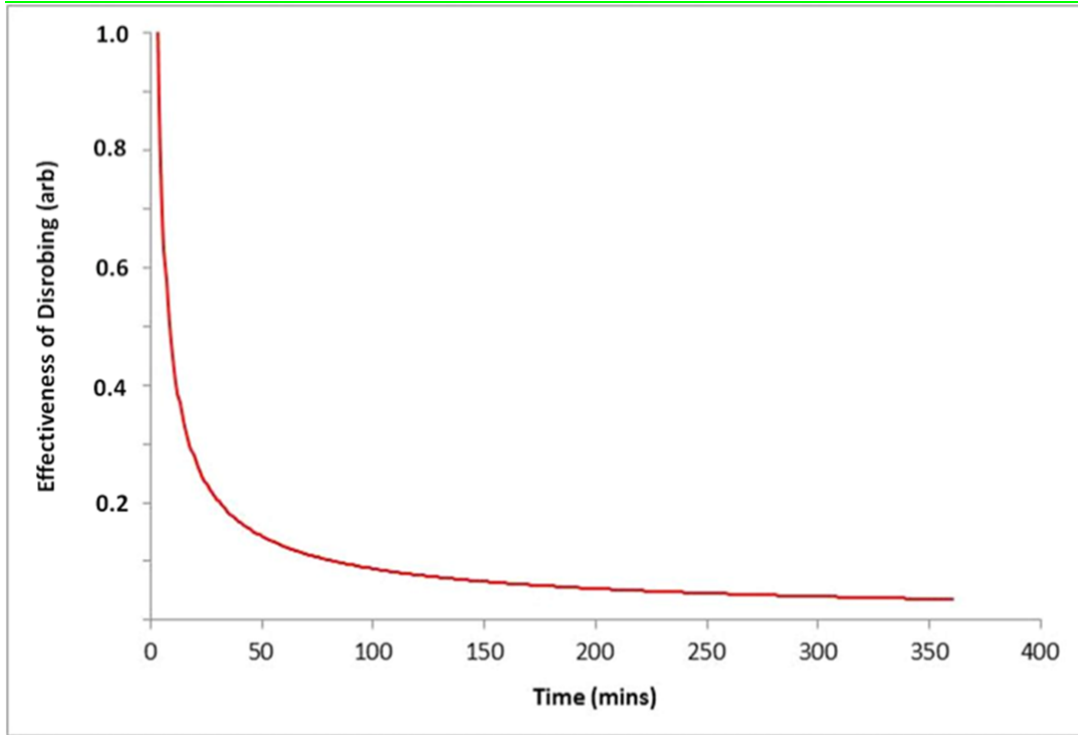


Figure 3: Relationship between the effectiveness of disrobing and time after exposure [26, 40].

v. *Disrobe: Recommended Practice and Rationale*

- Disrobing should be carried out as quickly as possible following exposure (ideally within 10 mins) in order to limit transfer of contaminant from clothing onto skin and to prevent secondary contamination through off-gassing of clothing.
- Disrobing should be carried out prior to showering to prevent contaminants being transferred from clothing to the underlying skin.
- If possible, clothing should be cut off rather than pulled over the head to prevent contaminant coming into contact with casualties' face. If appropriate cutting instruments are not available, casualties should be advised to hold their breath when removing clothes over their heads.
- The benefits of disrobing should be explained to help casualties understand why removal of clothing is necessary.
- Individuals refusing to disrobe should be asked to stand aside to prevent any delay in assisting cooperative casualties.
 - Further effort should be made to communicate with non-cooperative casualties, but this should not delay others.
- Responders should use any means available to provide casualties with temporary clean clothing. For example, foil blankets, linen, lastic sheets, blankets, etc.

C. Improvised Dry and Wet Decontamination

i. *Current Practice*

Improvised decontamination is defined as ‘the use of any immediately available method of decontaminating members of the public prior to the use of specialist resources’ [14]. Existing guidance highlights improvised decontamination as a rapid and effective method of removing contaminants from the skin. Various methods of improvised decontamination are outlined in current guidance. These include ‘dry’ decontamination methods such as paper towels, cloths, wet wipes [15, 16, 18, 19, 22, 23] and powders such as baking powder, cat litter and Fuller’s Earth [16, 18, 19, 22, 23]. Wet decontamination methods include the ‘rinse-wipe-rinse’ method [14, 19, 21] and the use of available water sources such as swimming pool showers, sprinklers and bottled water [18, 19, 21-23]. ‘Dry’ methods of improvised decontamination are often highlighted as alternatives to wet decontamination methods during extreme cold weather [15, 16, 22, 23].

The circumstances under which improvised dry decontamination or improvised wet decontamination would be most appropriate are often specified. Dry methods of improvised decontamination are not appropriate if casualties exhibit signs of exposure to caustic agents (e.g. itching or burning of the skin or eyes) [18, 19, 23] and wet decontamination is not appropriate if the contaminant is water-reactive [23]. Dry decontamination has been advocated by some to remove both liquid and particle contaminants [15, 16, 22] and has been suggested for use on non-liquid contaminants such as vapors or gases [23]. Dry decontamination should be considered when water is limited or not available [22], or when environmental conditions (e.g. cold weather) contraindicate the use of water.

Washing methods used during improvised decontamination are outlined in some guidance documents [14-16, 18, 19, 21-23]. Of these, three give details of a method for improvised wet decontamination; in all cases, the rinse-wipe-rinse method is stated to be the optimal method [18, 19, 21]. The rinse-wipe-rinse method involves rinsing the skin with water (soapy water can be used, if available), wiping the skin with a washcloth or sponge, and then rinsing the skin again with water.

There is considerable variation in recommended methods for improvised dry decontamination: seven of the identified guidance documents make some recommendations [14-16, 18, 19, 22, 23]. Of these, 3 suggest that the skin should be blotted during dry decontamination [15, 16, 22], two suggest that the skin should be wiped during dry decontamination [14, 23], and two suggest that the skin should be blotted and rubbed [18, 19]. Only two guidance documents provide full instructions for carrying out improvised dry decontamination which include: blotting and rubbing exposed skin surfaces from the face and neck downwards, using sufficient absorbent material to avoid spread of contaminant and not blotting or rubbing too aggressively to avoid driving contaminant into the skin [18, 19].

ii. *Prior Evidence*

Research suggests that improvised dry decontamination may be most effective for removing liquid contaminants from the skin whilst improvised wet decontamination (rinse-wipe-rinse method) may be more effective for removing particulate contaminants [41]. In terms of improvised dry decontamination, a variety of readily available absorbent products have been shown to be effective [26, 41]. These include materials such as paper towels, wound dressings and incontinence pads (Figure 4), as well as absorptive powders such as Fullers' earth. A study to establish the most effective method for improvised dry decontamination indicated that blotting skin followed by rubbing removed the most contaminant [42]. The study also demonstrated that blue roll and incontinence pads were similarly effective for removing liquid skin contamination, supporting the assertion that (i) any dry absorbent product can be used for improvised dry decontamination and (ii) the speed of decontamination is more important than the specific product used [26, 43-46].

Recent evidence supports the assertion that the rinse-wipe-rinse method can be an effective method for improvised wet decontamination [41]. However, studies examining the effectiveness of the rinse-wipe-rinse method often use soap which may not be immediately available at the scene of an incident. Studies examining the effects of water-based improvised decontamination for chemical burns have shown that early water decontamination can reduce the severity of the injuries caused by chemical exposure [47].

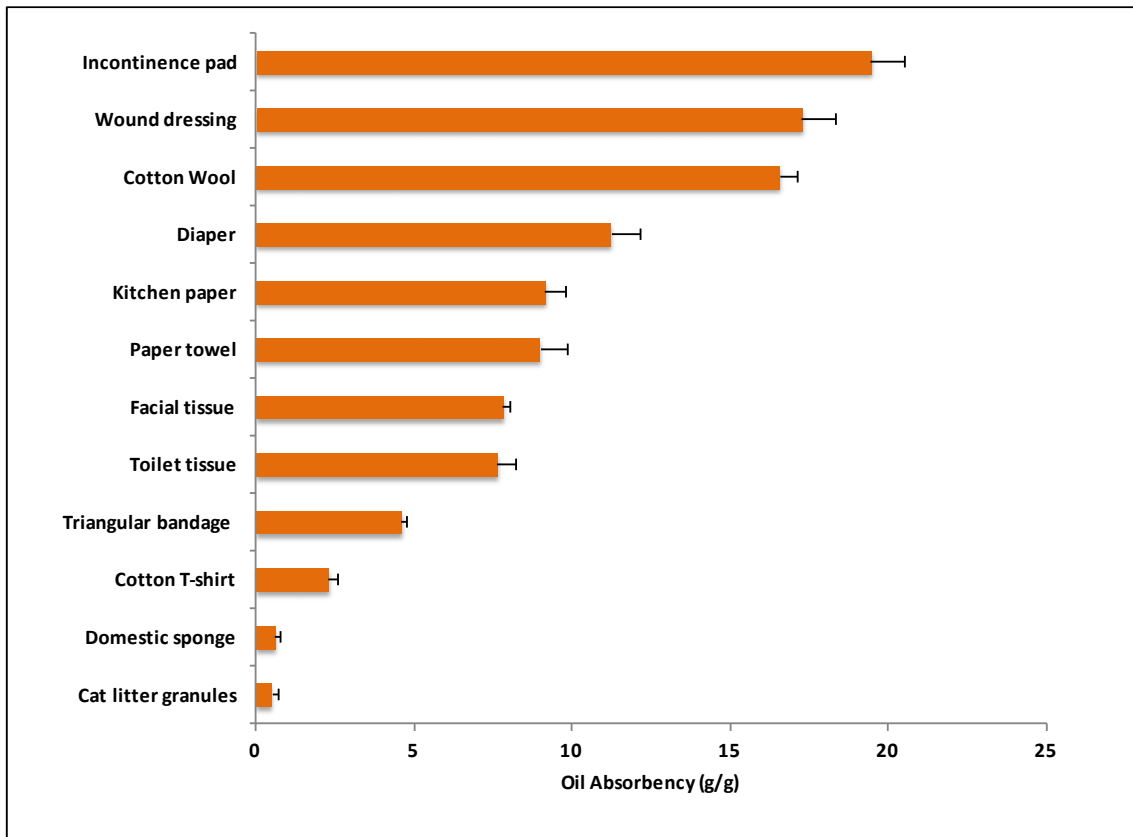


Figure 4: Range of absorbencies (gram of oil absorbed per gram of test product) for materials that may be readily found in ambulances or the domestic environment. Data provided for illustrative purposes only and does not represent an endorsement of any particular type of product.

iii. New Evidence

Recent evidence suggests that dry decontamination is most effective when (i) the contaminant is a liquid [40, 41, 43, 45, 48, 49], (ii) the contaminant is not caustic [26, 50], (iii) the weather is cold [51] or (iv) water is limited or not available. Improvised wet decontamination is more appropriate when the contaminant is particulate [41] or caustic [47, 52].

For improvised decontamination to be effective, it will be necessary for those affected to be provided with clear instructions on how to decontaminate themselves. In a field study of dry decontamination methods, volunteers carried out improvised dry decontamination during a simulated chemical incident [42]. Volunteers who did not receive specific instructions on how to decontaminate themselves used less absorbent material and did not decontaminate themselves from the head down; actions which could have resulted in further spread rather than the removal of the contaminant. This is in alignment with research into other methods of decontamination that have shown that effective communication is essential in order to prevent confusion and undertake successful decontamination [27, 28].

iv. *Knowledge Gaps or Uncertainties*

While the most recent evidence supports the operational use of rapid, improvised decontamination methods, evidence on whether improvised decontamination alone is sufficient is lacking. Current operational guidance is not clear on this issue; some suggest that improvised decontamination may be enough and that the decision to proceed with further decontamination should be made on a case-by-case basis [18, 19, 21]. Others state that further decontamination should always be carried out after improvised decontamination [14, 22, 23]. Further research is required to examine the effects of different decontamination methods conducted in series (i.e. improvised, gross and technical decontamination approaches) to inform decision-making processes at the scene of an incident.

Cibulsky & Kirk [51] suggested that it is necessary to specify a health outcome-based goal for decontamination; without such a goal, they suggest that decontamination itself becomes the aim and the emphasis will be on 'clean for clean-sake'. However, there is currently no health outcome-based goal for decontamination and decisions on the effectiveness of particular decontamination methods are made on a case-by-case basis as part of a dynamic risk assessment [19]. Further research is needed to develop health outcome-based goals for decontamination which can be employed by emergency responders at the scene to determine whether decontamination has (or is likely to be) effective.

- **Improvised decontamination should be carried out as soon as possible using any readily available materials.**
- **Improvised DRY decontamination should be the DEFAULT OPTION, particularly if the contaminant is a non-caustic liquid or water-reactive chemical.**
- **Improvised wet decontamination should be carried out if the contaminant is caustic or particulate in nature.**
- **Improvised decontamination should be carried out from head to toe, concentrating on exposed areas such as the scalp (hair), face, neck, arms and hands.**
- **A decision to follow improvised decontamination with gross or technical decontamination will need to be based on a dynamic risk assessment carried out by responders at the scene. Factors to consider include:**
 - **Nature of the contaminant.**
 - **Availability of resources.**
 - **Extent of initial contamination.**
 - **Continued or worsening presence of signs and symptoms.**
 - **Request from casualties to receive further decontamination.**

D. Gross Decontamination (Ladder-Pipe System)

i. Current Practice

Gross decontamination has been defined as, “the use of standard equipment to provide a planned and structured decontamination process for large numbers of the public prior to the availability of purpose designed decontamination equipment” [14]. Gross decontamination is considered to be an effective method for quickly decontaminating large numbers of people [14, 15, 18, 19, 21-23]. The most commonly stated method of gross decontamination is the Ladder Pipe System (LPS). The LPS decontamination method requires two fire pumps (positioned parallel to each other) and uses hoses and deck guns to create a high volume low-pressure shower corridor (Figure 5). The system can be set up rapidly without the need for specialized equipment. As casualties pass through the corridor, they are instructed to tilt their heads back [15], raise their arms [15, 22], spread their legs [15, 22], rub their skin [18] and occasionally turn either 90 degrees [15, 19] or 360 degrees [22].



Figure 5: Standard layout of the Ladder Pipe System (LPS) for gross decontamination.

Large volumes of water are sometimes recommended for decontamination [15, 22, 23] without mention of specific flow rates. Low water pressure is often recommended [15, 18, 22, 23] ranging between 50 and 60 psi [15, 22, 23]. Low water pressures have been suggested to avoid increased absorption of any contaminant [15, 22, 23], although there is no scientific evidence to support this assumption.

Optimal water temperature for decontamination is sometimes considered in current guidance [15, 17, 22, 23]. Tepid or lukewarm water is recommended to decontaminate casualties, with one document suggesting that water temperature should not be below 77 °F (25°C) for LPS decontamination [15]. It has also been suggested that cold water may be the most effective for decontamination, as it is readily available and results in “vasoconstriction

(closing of the pores), which prevents absorption of the contaminant into the skin” [21]. However, the same guidance also suggests that warm water may be needed to prevent hypothermia and thermal shock. It should be noted that there is absolutely no scientific basis for the existence of temperature-dependent skin pores.

Recommended shower durations for LPS decontamination vary. A minimum shower duration of 30 seconds has been suggested by some [15, 16, 22] whereas 45 seconds has been suggested elsewhere [18] with one document recommending no minimum duration [23]. Maximum durations include: 60 seconds [16], 90 seconds [18], 3 minutes [15, 23] and up to 5 minutes [22]. The latter guidance suggests that whilst 5 minutes should be considered a maximum shower duration, water contact time is optimized at 3 minutes but can be reduced to as little as 30 seconds in order to increase the throughput of casualties [22]. Operational observations have indicated that the practical duration of LPS decontamination may be average 15 seconds or less [53].

The use of soap or detergent has been advocated to optimize the LPS decontamination process [15-18, 22, 23]. Soap may be added to the decontamination process at the secondary or technical decontamination stage [15, 23], but others suggest that soap should be added to the decontamination process as quickly as possible. However, decontamination should not be delayed until soap can be provided [18, 22]. Alternatively, it has been suggested that casualties should undergo a 30 – 60 second shower with water alone, prior to the addition of soap [16]. Soap is deemed necessary to assist the removal of oily liquid hazards [15, 22, 23]. The type of soap or detergent is rarely specified, although ‘Baby shampoo’ has been indicated [22] whilst others have suggested that any type of mild soap can be used provided it is suitable for daily contact with skin [23]. Examples of detergents that are considered to be unsuitable include dishwasher detergent, laundry detergent and domestic cleaning products.

ii. *Prior Evidence*

While a number of guidance documents specify how casualties should walk through the LPS decontamination shower (i.e. tilting their heads back, raising their arms, occasionally turning, etc.) only one document states that casualties will need to actively wash while going through gross decontamination [19]. Simply spraying casualties with water may not be sufficient to remove contamination; casualties will need to actively wash while going through the shower to ensure decontamination effectiveness [54-56]. It has been suggested that washing efficacy can be further increased by the addition of detergent [26, 55, 56] and a washing aid such as a washcloth [54]; however, these products may not be available until technical decontamination is established: sourcing such products should not delay gross decontamination.

One study has suggested that a water pressure of between 60 – 70 PSI may completely remove a contaminant if applied to skin for 30 – 90 seconds [57]. Findings from in vitro studies have suggested that effective skin decontamination can be carried out in as little as 30 seconds [55, 56]. However, subsequent human volunteer trials have shown that for technical decontamination, the minimum time needed for healthy volunteers to undergo full and effective decontamination was 90 seconds [58]. Excessive shower durations could potentially facilitate a “wash-in effect”, resulting in enhanced dermal absorption (and thus increased toxicity) of the contaminant [26, 45, 51, 55, 56, 59-62]. A shower time of 90 seconds or less has been suggested as being sufficiently short to prevent the wash-in effect from occurring [26, 45]. A clear operational advantage of a shorter showering duration is that it will enable a larger number of casualties to be decontaminated [54].

Evidence for the effectiveness of soapy water versus water alone is mixed. While some studies have found that a 90 second shower using water alone may be sufficient to remove 100% of an oil-based simulant [57], detergent may be particularly effective for removing lipid-soluble chemicals [47] and there is some evidence to suggest that detergent solutions may remove around 40% more contamination than water alone [44, 45, 63]. Misik et al., [64] tested several different detergents against soman, VX, and paraoxon, and found that decontamination with detergent solution, when performed two minutes after exposure, resulted in significantly reduced morbidity. There is also evidence to support the effectiveness of decontamination with soapy water when carried out at 30 minutes post-exposure [65]. However, these studies did not directly compare the effectiveness of soapy water against water alone, and it is therefore not possible to establish whether decontaminating with soapy water improved outcomes compared to water alone from these studies.

Various studies have examined the effectiveness of using different detergents for optimizing decontamination. Detergents and soaps which have been tested include Argos, Florafree,

Dermogel and NeoDekont. Argos has been shown to be particularly effective for decontamination [55, 56, 66].

It has been suggested that rapid disrobing and decontamination is a form of first aid and is most effective if carried out immediately [26, 67]. Various research studies have examined the time window for effective decontamination using a range of different contaminants and decontamination methods. Bjarnason [65] found that washing with soap and water was effective for preventing death from VX poisoning when carried out at 30 minutes post-exposure. Studies have shown that for other agents (e.g. soman) response time may be even more vital, with even the most effective decontamination method (Reactive Skin Decontamination Lotion) providing insignificant protection against soman when decontamination was delayed for more than 3 minutes [68]. More recent studies performed as part of the UK's ORCHIDS program [40] have confirmed that the effects of decontamination are time-dependent (Figure 6).

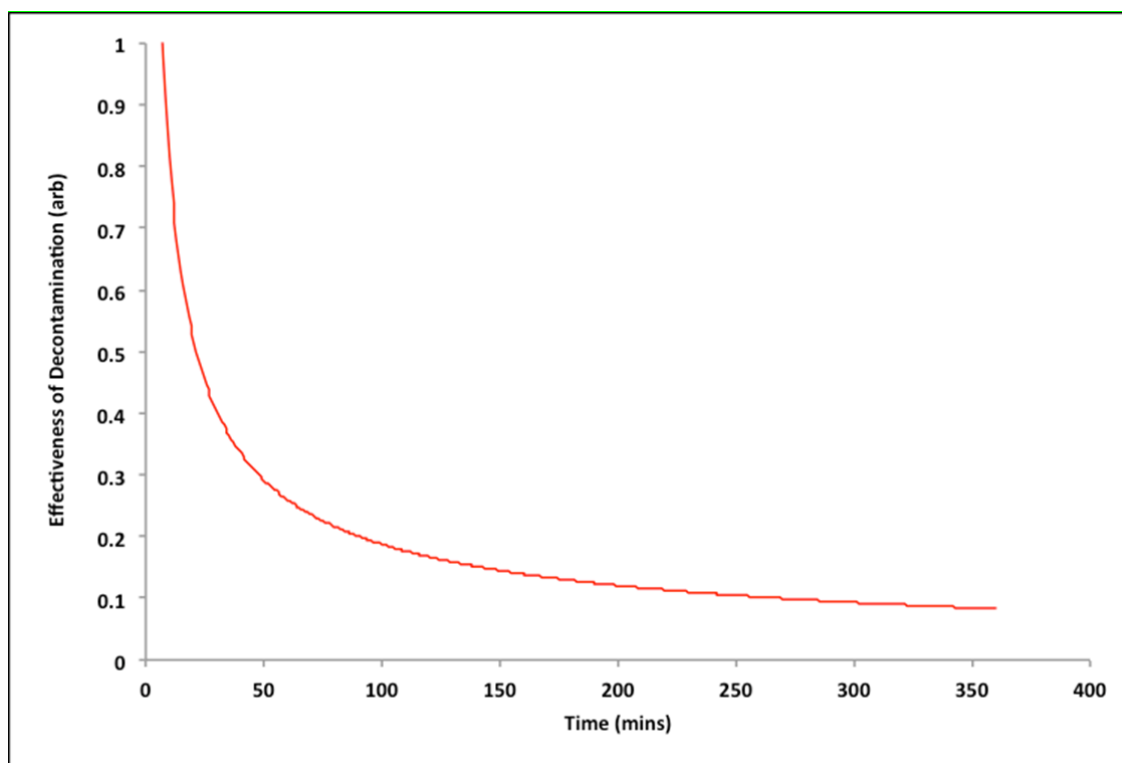


Figure 6: Relationship between effectiveness of decontamination and time post exposure [40].

iii. *New Evidence*

While the window of opportunity for performing effective decontamination will vary depending on the contaminant and the dose received, the evidence shows that performing decontamination at the earliest possible opportunity will save lives.

The current BARDA-funded ‘Advanced Studies of Mass Casualty Decontamination’ (ASoMD) project has subjected the Ladder-Pipe System (LPS) of gross decontamination to comprehensive evaluation in a series of linked studies. These studies are described in full elsewhere [1-13]. Key parameters that may impact on the effectiveness of LPS decontamination have been investigated and include hydrodynamics (water temperature and flow rate), effects of clothing and disrobing, detergents and delayed decontamination. The key outcomes of the ASoMD programme are summarized in Table 2.

LPS Parameter	Synopsis
Hydrodynamics & Temperature	Water flow rate and temperature do not generally have a significant impact on the effectiveness of LPS decontamination.
Clothing	The presence of clothing during LPS decontamination generally reduces the effectiveness of decontamination, with potential for transfer of contaminants from clothing to underlying skin. This supports the recommendation to disrobe <i>prior</i> to showering.
Detergents	The presence of detergent in LPS decontamination shower water does not significantly improve the effectiveness of decontamination, supporting the recommendation that gross decontamination should not be delayed for the introduction of detergent into shower water.
Delay to decontamination	A time-dependent decrease in the effectiveness of decontamination was frequently observed. Correspondingly, improvised and gross decontamination must be performed as rapidly as possible, otherwise decontamination may be ineffective at reducing exposure and minimizing illness and/or injury.
Duration of Decontamination	Short (15 second) duration LPS showering was found to be effective when performed in combination with active drying.

Table 2: Review of main research outcomes and recommendations from ‘Advanced Studies of Mass Casualty Decontamination’ (ASoMD) project.

Overall, the ASoMD program has demonstrated that the ladder pipe system of decontamination is generally effective for removing chemical contaminants from the skin surface. The importance of disrobing was confirmed as a critical step during these studies and emphasized the need to remove clothing *prior* to decontamination. The effectiveness of LPS decontamination was shown to be time-dependent, thus supporting the need to conduct gross decontamination as soon as possible following exposure. In general, there was no dependency on water flow rates and water temperatures for effective decontamination, nor did the presence of detergent improve the effectiveness of gross decontamination.

iv. Knowledge Gaps or Uncertainties

Gross decontamination systems such as the ladder pipe system have the advantage of being more structured and controlled than improvised decontamination and can be rapidly deployed without the need to wait for the arrival and set-up of bespoke decontamination equipment [26]. However, gross decontamination has several disadvantages, including the inability to provide warm water (associated with an increased risk of hypothermia) and little provision for protecting casualties' privacy [38]. The risk of hypothermia from showering with cold water is considerable, particularly if ambient air temperature is below 64°F (~18°C) [23]. Failure to protect casualties' privacy may result in delays to the decontamination process due to casualties being less willing to comply with recommended decontamination procedures [28]. Few current guidance documents [14, 19] recognize that hypothermia and lack of privacy are potential risks during improvised decontamination. Disrobe suits have been suggested as a means to protect casualties' privacy when undergoing improvised decontamination [14], although this is obviously dependent on disrobe suits being immediately available. An alternative to address issues of privacy and hypothermia risk is the Emergency Decontamination Corridor System (EDCS) ([15]. While being slower to set up than the ladder pipe decontamination system, this has the advantages of including salvage covers for privacy and portable heaters for warmth.

The consensus in the research literature is that warm water (90 – 105 °F; 32 – 41°C) is the most effective for decontamination. However, the ladder pipe system for gross decontamination does not generally allow for the provision of heated water. Recent studies have demonstrated that, when using the ladder pipe system, cold water (50°F; 10°C) is generally as effective as warm (95°F; 35°C) water, presumably as a result of the sheer volume of water used. Thus, whilst warm water for gross decontamination would be the preferred recommendation, cold water is acceptable for use with the LPS decontamination system. The use of cold water for other forms of gross (wet) decontamination would not be currently advisable due to a lack of evidence and the risk of hypothermia.

Current guidance is inconsistent regarding recommended shower duration, with estimates ranging from 30 seconds to 5 minutes; many do not specify shower duration for gross decontamination. In a study of shower duration (in mass decontamination units), a shower duration of 90 seconds was identified as optimal for whole-body decontamination [58]. However, further work is required to confirm the optimal shower duration for LPS decontamination. Consideration also needs to be given to shower duration for disabled or non-ambulant casualties. While healthy adult casualties should be able to effectively undergo decontamination in 90 seconds, this time is likely to be considerably longer for elderly casualties, or those with physical disabilities [58]. Hood et al. [69] carried out a study examining the effectiveness of decontamination for non-ambulant casualties. They found that decontamination was most effective if carried out for longer than 5 minutes. However, longer shower durations for gross decontamination presents difficulties, particularly if the water is unheated and casualty numbers are high. Furthermore, the extra time needed to effectively decontaminate non-ambulant casualties should be considered alongside the potential for greater shower duration to create a wash-in effect.

Finally, little attention has been paid to the potential difficulties in decontaminating hair. Wet decontamination is currently the preferred solution for decontaminating hair. However, the efficacy of current decontamination approaches and the impact of hair decontamination on current operational practices has not been addressed; there is currently no basis for recommending any specific practice for hair decontamination.

- **It is critical that gross decontamination is performed as soon as practically possible after exposure, ideally following improvised (dry) decontamination.**
- **Gross decontamination should not be carried out if the contaminant is water-reactive or if the ambient temperature is below 36 °F (2°C).**
- **Gross decontamination should not be delayed by improvised (dry) decontamination when casualties are experiencing immediate distress from the contaminant (e.g. due to contact with caustic substances).**
- **Gross decontamination will be most effective if casualties are asked to assist by actively washing themselves and occasionally turning through 90° whilst going through the shower.**
- **If possible, use warm water but do not delay decontamination if only cold water is available.**
- **A high volume, low-pressure mist of water should be used to decontaminate casualties.**
- **The duration of showering should not exceed 90 seconds.**
- **Soap or mild detergent solution may be used but do not delay decontamination to find a source.**

E. Active Drying

i. *Current Practice*

Current guidance is mostly consistent in stating that casualties should be dried following wet decontamination [15, 18, 19, 21-23]. Three of the documents specify that casualties should be dried with a “clean towel” [18, 19, 21]. In two of the documents, it is stated that the provision of a clean, dry towel should be included in the decontamination plan [19, 23]. In one of guidance documents, priority is given to drying the eyes, nose, and mouth [15]. In another guidance document, it is stated that post-shower drying should occur as quickly as possible at night time due to lower ambient temperatures [22].

ii. *Prior Evidence*

Physical cleaning of the skin surface (for example, through the use of a washcloth) can improve the effectiveness of decontamination by approximately 20% [54]. Where self-cleaning is not part of a decontamination procedure, the active stage of decontamination occurs after showering when the skin and hair is dried (for example, with a towel). In such cases, *the act of drying is actually the key step for removing residual contamination* [40, 55, 56]. Therefore, caution must be exercised when handling materials that have been used to dry individuals after decontamination showering as they are likely to be contaminated.

iii. *New Evidence*

Where civilian decontamination protocols have relied purely on technical approaches lacking explicit active washing instructions or washing aids, the process of drying following wet decontamination forms part of the decontamination process and, as a result, areas designated for drying and re-robe following decontamination must be treated as part of the warm zone rather than notionally ‘clean’. In recent years, this issue has been somewhat mitigated by a renewed emphasis on early evacuation, disrobe, improvised and gross decontamination steps prior to technical decontamination, incorporating dry decontamination or active-washing during wet decontamination [70].

iv. *Knowledge Gaps or Uncertainties*

Current guidance is generally lacking on the issue of whether active drying following decontamination is part of the decontamination process or how to manage residual contamination if it is likely to be present at the drying stage. Further research is required to examine the effects of different decontamination methods conducted in series (i.e. improvised, gross and technical decontamination approaches) to inform decontamination decision-making in this regard. It is likely that early interventions will mitigate the issue of

residual contamination during a toweling stage. However, further evidence is required to support this assumption.

v. *Active Drying: Recommended Practice and Rationale*

- **The provision of towels should be included in any incident response plan.**
- **Casualties should dry using a towel or other suitable material following any form of wet decontamination.**
- **In the absence of dry decontamination or active washing, towel drying represents a key stage in the decontamination process and so it is essential that towels or other suitable materials be made available to casualties following wet decontamination.**
- **Used towels should be treated as contaminated waste and the towelling stage should be considered to be within the warm zone (which may require local procedures to be revised accordingly).**

F. Technical Decontamination

i. Current Practice

The primary objective of technical decontamination is “to reduce a patient’s contamination to a level that is as low as possible in order to minimize the potential for secondary contamination of responders, receivers, other people, equipment, and facilities” [23]. Technical decontamination is also referred to as ‘mass decontamination’, ‘thorough decontamination’, and ‘secondary decontamination’. It is generally considered that technical decontamination is a more thorough method of decontamination and can be performed following improvised and/or gross decontamination to ensure that casualties are cleansed to an acceptable level. Technical decontamination may be necessary if casualties are to be transported to hospitals or other healthcare facilities for further treatment [22, 23]. Some current guidance recommends that if soap or detergent is necessary (for example if the contaminant is thick or oily), then technical decontamination is the stage at which it should be added to the process [15, 22, 23] and that a washing implement such as a washcloth or sponge should be provided to casualties during technical decontamination [15, 17, 23]. Caution is sometimes recommended as rubbing too hard may abrade the skin and enhance absorption of the contaminant [23].

ii. Prior Evidence

In most countries where a technical decontamination capability has been established, decontamination protocols are generally based on ‘perceived best-practice’ and are in alignment with local risks and requirements. Figure 7 shows a typical technical decontamination configuration, consisting of a large structure through which casualties move in gender-segregated corridors for disrobing, showering and re-robing. Specially trained personnel in Personal Protective Equipment (PPE) manage the process. A significant benefit to this approach is the control and containment of secondary contamination (e.g. clothing and personal belongings) and the ability to contain potentially contaminated effluent. However, technical decontamination approaches are slow to implement, resource intensive, and if managed poorly, decontamination may be sub-optimal.



Figure 7: Mass casualty decontamination unit (“MDI”) deployed by UK specialist responders. Photograph acquired during an exercise and shows a group of 10 individuals in high visibility ponchos (from “disrobe packs”) waiting to enter the unit in accordance with a “traffic light” system (inset, top left). A schematic of the unit (inset, top right) indicates position of disrobe area, two side corridors (each with five shower areas [“S”]) for decontamination of ambulant casualties) and a central corridor (used by responders to observe or instruct individuals) which can be adapted for processing non-ambulant casualties. Air heaters and a boiler for shower water are at the rear of the tent and so not shown in this image. Reproduced with permission of Public Health England ©2013.

Evidence to support the optimization of technical decontamination systems has recently been produced [48, 71] and has resulted in a range of specifications collectively referred to as the ‘ORCHIDS protocol’ (Table 3). For example, the use of a washing aid such as a washcloth can improve the effectiveness of decontamination by approximately 20% [54]. Furthermore, if casualties are actively performing a full-body wash, no further benefit is conferred by showering for longer than 90 seconds [58]. These parameters can be implemented within a range of different technical decontamination units to improve the effectiveness of decontamination and throughput of casualties. The ORCHIDS protocol has been tested in the UK, France and Sweden and has been shown to be at least as effective as existing national protocols at removing contaminants whilst at the same time improving casualty throughput [71].

Parameter	Optimal Condition
Shower water temperature	35°C
Shower duration	60 – 90 seconds
Detergent	0.5% (v/v) Argos™ or FloraFree™
Washing aid	Cotton washcloth.

Table 3: Summary of conditions for optimization of aqueous (shower based) technical decontamination according to the “ORCHIDS Protocol” [26].

iii. New Evidence

The most recent evidence to support the optimization of technical decontamination processes has focused on communication and casualty management (see Section G).

iv. Knowledge Gaps or Uncertainties

Guidance is inconsistent on whether technical decontamination will always be required following improvised or gross decontamination or whether technical decontamination will only be necessary in certain situations. It is suggested that technical decontamination will need to be carried out if soap or detergent is required [15, 22, 23] or if casualties need to be transported to hospitals [22, 23]. The need for technical decontamination must be based on a dynamic risk assessment; a process which would benefit from the development of appropriate decision-aiding tools.

Further research is needed to understand the cumulative benefits of serial processes (disrobe, followed by improvised, gross and technical decontamination) under a variety of different scenarios. Hazards associated with vapor risk or adverse environmental conditions must be considered and further evidence is needed on the risks associated with the use of enclosed decontamination units without controlled air circulation. However, it is likely that the cumulative effects of early disrobe and improvised and/or gross decontamination steps may mitigate against vapor risks inside technical decontamination units (although evidence is required). Finally, it is conceivable that a delay in the arrival and deployment of a technical decontamination asset may limit its utility to being a precautionary process or for reassurance of casualties and/or emergency responders.

- **Planning should include the provision of resources that will optimise the technical decontamination process (e.g. disrobe and re-robe kits, washing implements, detergent etc.).**
- **If disrobing has not already taken place, casualties should be provided with a disrobe pack and instructions on how to disrobe.**
- **Technical decontamination focuses on thoroughness rather than speed and should therefore be carried out following improvised and/or gross decontamination.**
- **The optimised parameters for technical decontamination include a shower water temperature of 35°C, duration of 60 - 90 seconds, addition of mild detergent to the shower water and the provision of a washcloth for each casualty.**
- **Casualties should be instructed to wash from head to toe while going through the shower.**
- **Washcloths will be a potential source of secondary contamination and should therefore be treated and disposed of as contaminated waste.**

G. Communication and Casualty Management

i. *Current Practice*

The importance of effective communication with casualties during mass decontamination is often acknowledged in current guidance [15-19, 22, 23]. However, few explain *why* communication is important or highlight specific recommendations for responder communication strategies. A good communication strategy is identified as important because a lack of information may undermine trust in personnel and increase non-compliance [16, 18, 19], provision of information may reduce casualties' concerns [23] and provision of information may mitigate against stress and anxiety [19].

Recommendations for emergency responders, in terms of *what* information should be communicated to casualties and *how* information should be communicated to casualties are sometimes included. Information which should be communicated includes: information about the incident and about why decontamination is necessary [16, 18, 19, 23], information about what casualties should expect as they go through decontamination [16, 23], instructions on how casualties should disrobe [16], information about adverse health effects to self and family members if decontamination is not carried out [23] and what is being done to help casualties and how they can help themselves [18, 19]. Recommendations about how information should be communicated include: pictorial instructions with easy to follow step-by-step decontamination instructions [16, 18], pre-recorded audio or video messages to provide basic instructions to casualties [16, 23], debriefing sessions with groups of casualties in the cold zone [16], communicating information to members of the public as quickly as possible [23]; listen to casualties' concerns (USDHS, 2014); provide consistent information (USDHS, 2014) and instruction sheets in the most common languages used in the community [18, 23].

ii. *Prior Evidence*

Effective communication is essential during incidents involving decontamination. Examples from real incidents show that a failure to communicate effectively can result in reduced public compliance and increased public anxiety [36, 72]. Several methods of communicating information to members of the public during decontamination have been examined: these include the provision of pictorial instructions prior to decontamination [54, 73], the provision of pre-recorded instructions via loudspeaker [27] and demonstration of disrobing and showering procedures by Fire Department personnel. Of these methods evaluated, the provision of instructions via loudspeaker and practical demonstration by FRS personnel resulted in improved efficiency of the decontamination process. The results from studies looking at the efficacy of pictorial instructions were mixed, with pictorial instructions not resulting in improved decontamination efficacy [54]. Possible reasons for this were that pictorial instructions were provided prior to (rather than during) decontamination and that

pictorial instructions were not visible within the decontamination shower. It is also possible that while pictorial instructions did not result in improved physical efficacy of decontamination, they may result in reduced confusion, which could improve the overall process of decontamination.

iii. New Evidence

A recent research program has used a variety of methods to identify what constitutes an effective responder communication strategy during mass decontamination including mass decontamination field exercises [74, 75], online visualization experiments [27, 76] and mass decontamination field experiments [77]. This research makes three key recommendations for effective responder communication strategies [78]. First, emergency responders should communicate in a health-focused way about why decontamination is necessary. This should include explaining how decontamination can help to protect oneself and one's family. Second, emergency responders should communicate honestly and openly about any actions that they are taking. Third, emergency responders should provide sufficient practical information to enable members of the public to successfully undergo decontamination. When such a communication strategy is employed, it results in increased speed and efficiency of the decontamination process, as well as improved perceptions of responder legitimacy; a factor that has been shown to increase public compliance with decontamination [27, 75, 77]. Despite the fact that perceptions of responder legitimacy have consistently been shown to be an important factor in the successful management of mass decontamination, current guidance rarely recognizes the importance of trust and legitimacy in responders for facilitating successful management of mass decontamination [16, 19].

iv. Knowledge Gaps or Uncertainties

Recent research evidence provides clear direction on how to develop an effective communication strategy for emergency decontamination. Using these approaches will help to increase compliance with decontamination processes, improve the speed and efficiency with which decontamination is conducted, reduce anxiety and promote the legitimacy of and trust in emergency responders. However, further research is needed to acquire a better understanding of the general public's existing knowledge and acceptability of different decontamination interventions (e.g. wet vs. dry). A well prepared and knowledgeable public would facilitate the smooth running of decontamination processes and a better understanding of the acceptability of decontamination interventions, particularly in minority and at risk groups, could help to further refine emergency responders' communication and casualty management strategies.

- **What to communicate?**
 - **Provide health-focused information about why decontamination is necessary.**
 - **Explain the benefits of undergoing decontamination, in terms of protecting oneself and others.**
 - **Explain that failure to undergo decontamination can result in secondary contamination of other people and places, including home and family.**
 - **Communicate openly and honestly about the nature of the incident and any actions that are being taken.**
 - **Provide sufficient practical information to enable members of the public to successfully undergo mass decontamination and so improve the speed and efficiency of the overall process.**
- **How to communicate?**
 - **Loudspeaker.**
 - **Pre-recorded or pre-scripted messages.**
 - **Practical demonstration.**
 - **Pictorial instructions.**

Special Requirements: identifying and decontaminating vulnerable and at-risk casualties

i. Current Practice

Casualties can be broadly categorized into three groups for decontamination: *ambulatory casualties* (e.g. those who are able to carry out self-decontamination), *non-ambulatory casualties* (e.g. those who are unconscious or unresponsive, or have a disability which prevents them from undergoing self-decontamination) and *potentially non-ambulatory casualties* (e.g. those who may be able to undergo self-decontamination only if appropriate support is in place (e.g. children, elderly, those with visual/ hearing difficulties, non-English speakers, those with a cognitive disability)). This section will focus on the decontamination of non-ambulatory casualties, and potentially non-ambulatory casualties.

Some groups may have special needs in relation to decontamination or may be particularly at risk from the effects of contamination or from the decontamination process itself. A number of guidance documents identify vulnerable groups to include: children [15, 16, 18, 21-23]; the elderly [15, 21, 23] the physically impaired, but still able to walk [16, 21-23]; the hearing impaired [15-18, 21-23]; non-English speaking or Low English Proficiency (LEP) [15-18, 21-23]; the cognitively impaired [15, 16, 21, 23] pregnant women [18, 21, 23]; and those who use mobility aids [16, 21, 23]. The need to categorize at-risk individuals by functional needs is emphasized in the ASPR “CMIST” framework which identifies vulnerable individuals based on communication, maintaining health, independence, services support and transportation needs [79].

Five guidance documents identify casualty prioritization as a key part of decontamination procedures [15, 18, 19, 22, 23] and two documents discuss how vital signs and symptoms of casualties determine prioritization [15, 19]. One guidance document states that casualties who are identified as breathing and conscious but non-ambulatory should be regarded as high priority and describes how such casualties should be removed from the perceived area of greatest contamination and relocated to an area of relative safety [19]. Conversely, one document states that the highest priority for decontamination is ambulatory casualties who are symptomatic, with non-ambulatory casualties as secondary priority [15].

Three guidance documents state that casualties need to be decontaminated in order of priority and that higher priority should be given to the very young and elderly [15, 16, 23], whilst one document states that those who are pregnant and/or have chronic medical conditions should also be prioritized [23].

Two guidance documents provide a definition of a non-ambulatory casualty where the casualty is a victim who is unconscious, unresponsive, or unable to move without assistance [15] or a non-ambulatory casualty is mobility impaired, for example either stretcher or wheelchair bound [23]. Multiple ladder pipe systems are recommended for use so that the decontamination corridor can process both ambulatory and non-ambulatory casualties [15]. Alternatively, buildings and facilities used for decontamination need to be suitable for disabled people [18], or specialized equipment should be used for decontaminating non-ambulatory casualties, such as roller systems or gurneys [22, 23]. Documents vary in the amount of guidance they provide for decontaminating non-ambulatory casualties, with one document specifying five stages for the decontamination of non-ambulatory casualties [22]. Additional personnel are recommended to assist with decontaminating non-ambulatory casualties [15, 22, 23], with one document recommending that at least 8 additional personnel are required and that emergency responders should provide one-on-one assistance to non-ambulatory children [22].

Four guidance documents recognize that physically impaired casualties who are still able to walk will necessitate special consideration [16, 21-23]. Two guidance documents specifically state that medical triage should be carried out prior to decontamination [16, 23] and that all casualties should be asked if they have a physical impairment that may require them to be assisted through the decontamination process [16]. One document states that casualties with mobility impairments may need to be treated as non-ambulatory [22], while another recommends the implementation of a buddy system in which ambulatory casualties assist those casualties who may have difficulty in undergoing self-decontamination [23]. Supportive aids such as walking aids and prosthetic limbs may be critical for a casualty to maintain independence [16, 22, 23]: removal of supportive aids is likely to cause anxiety and distress amongst those who rely on them and so casualties should be allowed to retain supportive aids during decontamination [16]. Communicating information about the decontamination process, including how supportive aids will be handled may increase compliance with the process [23].

Hearing-impaired casualties require special consideration during decontamination [15-18, 21-23]. Several guidance documents recognize that hearing-impaired casualties may benefit from being allowed to retain their hearing aids during the decontamination process. Similar consideration has also been extended to those who are non-English speaking or of Low English Proficiency (LEP) [16, 18, 22, 23], with recommendations for the inclusion of interpreters in the decontamination team [18, 22]. One guidance document also recommends that LEP and/or non-English speaking casualties undergo decontamination with others who speak the same language [22]. Some guidance documents recommend that instructions for each step of the decontamination process should be available in multiple languages or in the form of signs and/or pictographs [16, 18, 22, 23]; these recommendations will improve the process for those with LEP and/or hearing impairments.

Visually impaired casualties will require special consideration during decontamination [15, 17, 21-23] and it has been suggested that sighted casualties should be encouraged to assist those who are visually impaired [18].

Decontamination plans should consider the needs of children [16, 18, 21-23]. Four of the guidance documents specifically state that the psychological needs of children should be planned for during mass decontamination and that every effort should be made to keep children with their families during the decontamination process under the supervision and assistance (where necessary) of emergency responders [16, 18, 22, 23].

Several different procedures for managing children through the decontamination process have been suggested. For example, it has been recommended that objects such as laundry baskets or baby baths be made available to carry infants or children through decontamination [16, 23]. However, it may be more beneficial for parents or guardians to carry their child, unless there is an overriding need to separate the child from its parents [16]. One document recommends that parents or guardians should wash and rinse their child while another person holds or cares for the child [22]. In the case of a child who is alone, emergency responders should make eye contact with the child and explain what is going to happen [23], or cartoon videos and/or cartoon posters should be utilized as a way of communicating basic decontamination instructions while decreasing the potential for fear among children [16]. One guidance document recommends that children be covered in foil blankets post-decontamination to prevent risk of hypothermia [16].

Older casualties may also require special consideration during decontamination [15, 18, 21, 23] as they will be at increased risk from hypothermia [15, 23] and may be dependent on family or primary carers for information and assistance [18]. One document specifically recommends the utilization of a buddy system, whereby an ambulant casualty can assist an elderly casualty through the decontamination process [23]. Casualties with chronic medical conditions may also require special consideration during decontamination as they may be more susceptible to the effects of chemical contamination [23]. Again, the implementation of a buddy system to assist with the management of medication as well as any distress experienced during the process has been recommended [23]. However, none of the guidance documents reviewed provide detailed recommendations for the management of those with chronic illnesses.

Decontamination plans must also consider pregnant women [18, 21, 23]. Visual identification or announcements for pregnant women to identify themselves to emergency responders have been recommended [18].

Finally, decontamination plans must consider those who use mobility aids and/or sensory aids (such as glasses and hearing aids) which casualties should retain in order to maintain normal functionality [16, 21, 23]. A variety of ways to deal with such items have been suggested and include (i) removal, cleansing and return to casualties prior to

decontamination [17], (ii) removal for cleansing whilst casualty undergoes decontamination [22] and (iii) cleansing whilst worn/used by casualties during the process of decontamination [16]. Casualties should be informed how their items will be handled in order to improve compliance [23]. It should be noted that one guidance document states that hearing aids cannot be decontaminated [16].

ii. Prior Evidence

Certain groups may be particularly susceptible to the effects of a contaminant and should therefore be prioritized during decontamination [72, 80]. A non-ambulatory casualty has been defined as symptomatic, seriously injured in an accident or to have a pre-existing disability [54]. Researchers have suggested that a separate non-ambulatory line for decontamination should process casualties who are physically impaired and reliant on mobility aids [81]. Emergency responders should ask casualties if they have any physical disabilities, and if they require any assistance through the decontamination process [73, 82], as physical disabilities may not be immediately obvious.

Suggested transportation methods for non-ambulatory casualties include: a stretcher that requires four people, a large-wheeled stretcher that requires one or two people or plastic chairs [81]. During a decontamination exercise involving physically disabled casualties; plastic chairs were used as a replacement for the backboards of the roller system [73]. Emergency responders were unable to help these casualties transfer safely; and the authors concluded that it is important for emergency responders to be trained on lifting and transferring non-ambulatory casualties. Similarly, a decontamination exercise identified challenges experienced by emergency responders as a result of wearing PPE; amputee casualties were slipping through responders' hands when they lifted them up [83].

Braue et al [81] recommended the implementation of a buddy system to assist those with physical impairments, a suggestion which has been implemented in a recent guidance document [23]. Research findings support the use of a buddy system, suggesting that casualties may be willing to help others during decontamination provided they have received effective communication from responders about the importance of undergoing decontamination [28, 74, 75, 84].

The outcomes of recent studies have suggested that casualties with hearing impairments should (i) be encouraged to go through the decontamination process with non-impaired individuals [73], (ii) be allowed to keep their hearing aids during the decontamination process [85], (iii) be provided with instructions in text and pictorial formats [86] and (iv) be given instructions via emergency responders' body language [87].

Affected individuals are likely to experience difficulties understanding and following instructions during a disaster [88, 89] and may also lack confidence in the way information is

communicated [90]. Methods to improve the decontamination process for non-English speaking casualties include the provision of interpreters in the decontamination team [73], instructions in pictorial format [91] and encouraging casualties who speak the same language to undergo decontamination at the same time [73].

Recent recommendations for the management of visually impaired casualties include the provision of large, clear signage [91], ensuring that visually impaired casualties do not become separated from their eyeglasses [85] and implementation of a buddy system [84].

Casualties with pre-existing cognitive impairments may require increased assistance during decontamination. Such individuals may include those with reduced attention, processing speed and memory [92-94] and, in some instances, may experience delusions and paranoia [95]. A stressful situation can intensify a person's cognitive impairment, and trigger irrational behavior like aggression, which may lead to non-compliance [96-98]. Emergency responders may help keep those with cognitive impairments calm by expressing empathy and reassurance [96-99].

There are several physiological, psychological and developmental vulnerabilities in children that can pose challenges during decontamination [85, 100]. Children are particularly vulnerable to negative psychological reactions as a consequence of a traumatic event, and their mental health needs should be considered in disaster preparedness [85, 101-106]. A number of studies have recommend that families are decontaminated together to prevent anxiety reactions in children [105, 107-109], whereas unaccompanied children should be assisted throughout the disrobe [107, 110, 111] and decontamination processes [105]. Children may be reluctant to undress in the presence of strangers [107] and so the need for assistance may need to be balanced against the need for privacy.

As well as increased vulnerability to negative psychological reactions, children are also physiologically more susceptible than adults. This includes increased physiological vulnerability to contaminants [72, 80], as well as increased susceptibility to hypothermia [72, 108, 111]. Some have suggested that children should be decontaminated as early as possible on account of having skin which is more permeable than adults [112], although there is little or no evidence to substantiate this particular aspect. However, research also recommends that families be decontaminated together [108]; this apparent conflict may need to be resolved on a case-by-case basis. To reduce the risk of hypothermia, it is recommended that warm water is used to decontaminate children [81, 107] and, where appropriate, heaters are used throughout the decontamination process [108].

Older adults are at increased risk of suffering from sensory, physical and cognitive impairment or chronic illness [85, 113-115]. These vulnerabilities are likely to create difficulties in undergoing decontamination in terms of challenges with communication [113], understanding [85] and increased anxiety [115]. To meet the needs of the elderly during decontamination, instructions should be worded simply [85] and written instructions should

be presented in a large font [113]. The use of a buddy system, in which physically able casualties assist those who are less able, has also been shown to be effective [84].

Pregnant women have been identified as a vulnerable group due to their physical and psychosocial needs [116-119]. Pregnant women should be decontaminated first due to the adverse health effects placed on both pregnant women and their unborn child [119] and it has been suggested that emergency responders ask all women if they are pregnant prior to undergoing decontamination [85, 120].

iii. New Evidence

A recent exercise has demonstrated the practicality of the buddy aid system where ambulant, uninjured casualties assisted the evacuation of simulated non-ambulant and visually-impaired casualties to a decontamination area. [12]. The same study showed that the ad hoc use of available equipment (such as stretchers or wheelchairs) by emergency responders to process non-ambulant or visually impaired casualties reduced delays associated with physically carrying casualties through gross (LPS) decontamination. Moreover, the clinical efficiency of the decontamination process was not adversely affected by placing casualties on a stretcher or wheelchair. Results from an online survey of emergency responders [4] indicated that the majority of respondents would expect a member of their team to assist physically impaired casualties who were unable to undress/redress [121].

iv. *Knowledge Gaps or Uncertainties.*

There is a general need to improve consistency and coverage of issues and recommendations relating to the management of decontamination for vulnerable and at-risk populations in existing guidance. Provision of training and exercising for emergency responders involving casualty actors or volunteers from at-risk or vulnerable groups is needed to generate evidence to support guidance statements. Further research is required to test the effectiveness of emergency decontamination protocols for at-risk and vulnerable groups. Different communication strategies and strategies to manage non-ambulant casualties need to be systematically evaluated in controlled trials and field exercises. Finally, community engagement and pre-incident public education concerning actions to take during incidents requiring emergency decontamination could go some way towards preparing the public, including those with additional needs that emergency responders will need to consider. Such initiatives should also be used to generate further evidence on the effectiveness of public education interventions for low probability, high impact events.

v. *Special Requirements: Recommended Practice and Rationale*

Note: these recommendations specifically refer to gross (ladder pipe) decontamination. Arrangements should be in place to process individuals with special requirements during technical decontamination.

- **Identify and prioritise all individuals with special requirements. These include, but are not limited to, individuals who are:**
 - **Young, elderly, pregnant, physically or mentally impaired, demonstrating signs of exposure to hazardous chemicals, known to have come into contact with or close proximity to the hazardous chemical, unable to understand verbal instructions or are otherwise unable to perform decontamination unaided.**
- **Disrobe and decontamination should not be delayed for the arrival of specialist resources.**
- **Following disrobe and interim decontamination (if performed), use any available equipment or items to carry casualties with special requirements through the decontamination corridor.**
- **Good communication (verbal, signage, or body language) is vital to reassure and instruct the casualties.**
- **Consider whether medical devices (e.g. walking sticks, eyeglasses, hearing aids, etc) can be decontaminated; if so, allow casualties to retain these items during decontamination.**
 - **Some supportive aids (e.g. certain types of prosthetic limbs) may not be amenable to decontamination.**
- **Implement a buddy system wherever possible.**
- **Families and groups of individuals who speak the same language should undergo decontamination together (if possible).**

Summary

The draft recommendations presented in this document are based on an evaluation of current practices, past research or recent studies performed as part of the “Advance Studies of Mass Decontamination (ASoMD) Project” sponsored by the US Biomedical Advanced Research Development Authority (BARDA).

The new guidance requires two operational changes that specifically relate to primary response incident scene management (PRISM):

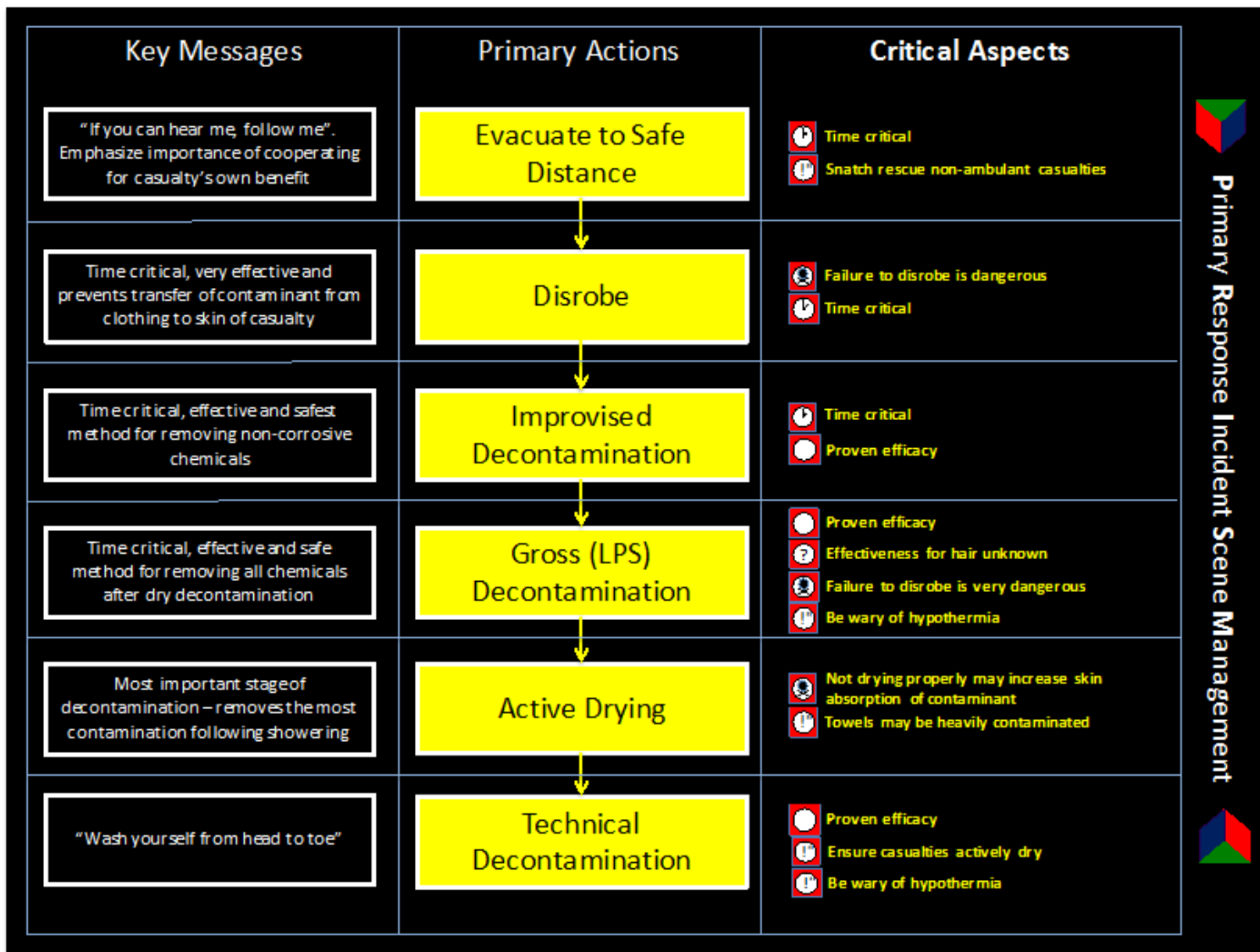
1. An understanding that the initial response is *time critical*. Evacuation, disrobe and improvised and/or gross decontamination *must be completed as rapidly as possible* in the likely absence of any specialist resources.
2. In order to reduce the complexity of dealing with a range of potential issues, casualties should initially be considered as being in one of two categories; ‘standard’ or ‘special requirements’. Individuals who are both ambulant and able to understand verbal instructions should undergo disrobe and improvised/gross decontamination with minimal reliance on emergency responders. Casualties who, for whatever reason, are either non-ambulant or unable to comply with verbal instructions should be helped to disrobe and undertake improvised decontamination and then carried through gross decontamination on a stretcher, wheelchair or any other practical means by emergency responders in order to avoid lengthy delays.

The salient features of the PRISM process are summarized in Figure 8.

Some of the recommendations in this document will pose new challenges for those engaged in planning and preparing for Hazmat and CBRNe incidents. For example, the development of improved methods of communication, the provision of auxiliary items (e.g. washcloths), improved processes for handling potentially contaminated waste (previously considered to be clean) and procedures for new aspects such as active drying.

A number of residual gaps in incident response processes have been clearly identified: these require investigation to ensure that any future revisions to the PRISM guidance utilize evidence-based practices which are casualty-focused to facilitate the most effective outcome. In particular, further work is ongoing to identify any specific considerations relevant to the decontamination of hair and to develop a simple decision-aiding tool to allow first responders to determine the most appropriate course of action during the primary response phase. For example, are there any instances when decontamination will not be required after disrobing and can improvised or gross decontamination be considered sufficient to reduce further interventions? The perennial question of “how clean is clean” remains to be comprehensively addressed. However, laboratory studies undertaken as part

of the ASoMD project [2, 3, 7, 10] can provide some general guidance on this issue: each stage in the PRISM process results in an approximately 10-fold decrease in contamination (Figure 9). It must be emphasized that this represents a rough 'rule of thumb' and may vary according to the initial contamination density and the nature of the contaminant, amongst other factors.



Primary Response Incident Scene Management

Figure 8: Salient features of the Primary Response Incident Scene Management (PRISM) process.

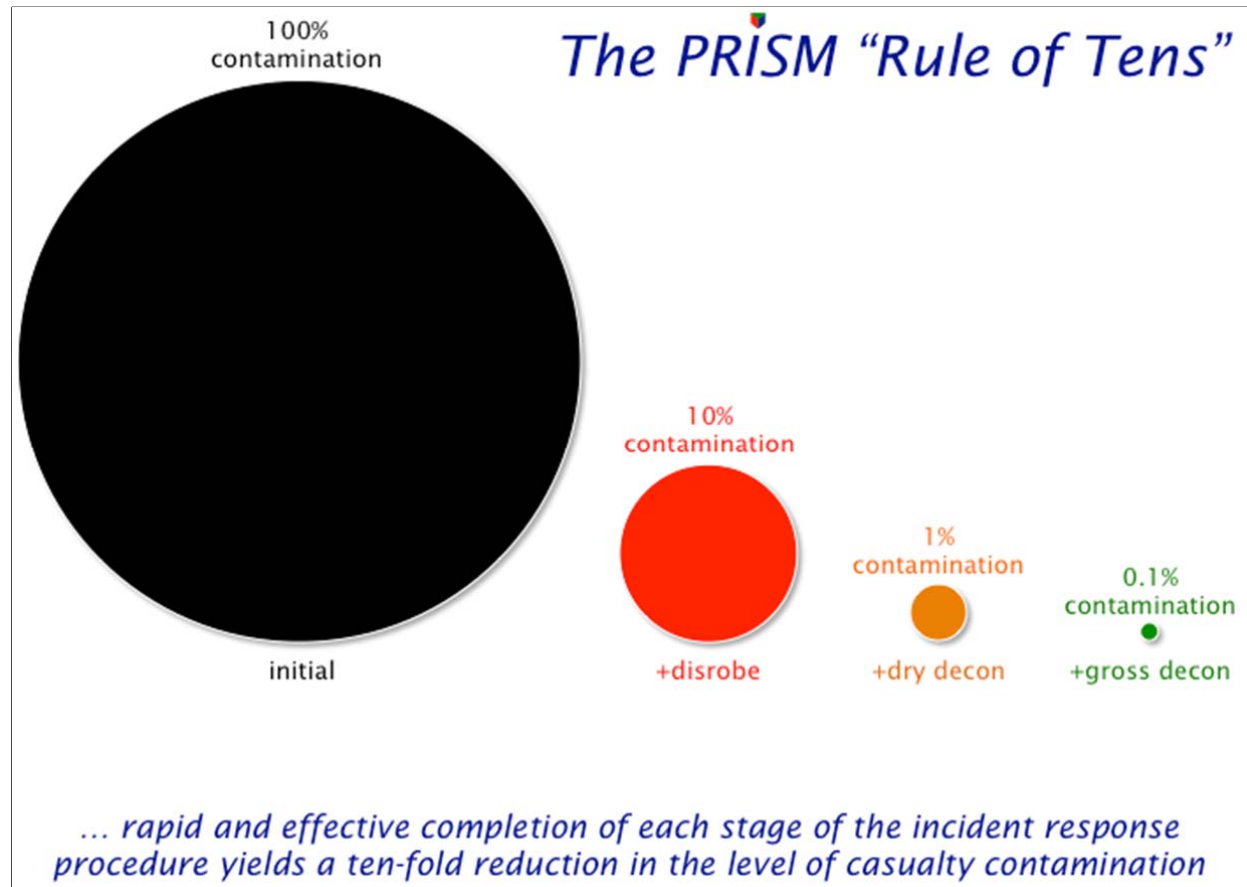


Figure 9: PRISM "rule of tens" for estimating the contribution of each stage of the incident response procedure. This diagram is for guidance only – the actual percentage removal of contaminant will be dependent on the prevailing conditions, the speed of the initial response, the initial dose (contamination density) and nature of the contaminant.

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