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Methods of Skin Decontamination Following Exposure to Toxic Industrial Chemicals and Chemical Warfare Agents

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Abstract:

Purpose: *Exposure of the body to the harmful effects of toxic substances, such as chemical warfare agents or toxic industrial chemicals, can cause serious damage to the skin and internal organs. Therefore, to mitigate negative effects on health, it is crucial to shorten exposure time using decontamination methods. The aim of this paper is to analyze the types of decontamination based on the implementation methods (dry, wet and mixed) in order to identify the most suitable type for specific practical applications. Ready-to-use decontamination kits, including Reactive Skin Decontamination Lotion (RSDL), are also discussed due to their high effectiveness, and the use of both chemical and physical methods for neutralizing toxic agents. Finally, the process of skin and hair is analyzed from the perspective of humans and animals.*

Design/Methodology/Approach: *The study used literature analysis and deductive reasoning as its core methods, enabling us to integrate knowledge from the reviewed works and substantiate conclusions tied to the research purpose.*

Findings: *Rapid skin decontamination is crucial after exposure to toxic industrial chemicals or chemical warfare agents. No single universal method exists, the choice depends on the substance and situation. Dry methods (adsorbents, kits) are recommended first to avoid increasing skin absorption, wet methods (water, soap) can reduce exposure but may boost absorption if used alone at the start. Combining dry and wet methods can increase effectiveness, especially for persistent toxins.*

Practical implications: *Emergency response plans should prioritize the availability and use of dry decontamination materials (e.g., adsorbents, commercial kits) as a first-line approach. Training for responders and at-risk personnel should include correct selection and application of decontamination methods. Institutions and facilities at risk of chemical incidents should have protocols of decontamination. Ongoing education and drills are essential to ensure preparedness for mass casualty chemical incidents. Decontamination strategies should also account for the potential generation and management of secondary contamination.*

Originality/Value: *This article provides a evaluation of both traditional and modern methods of skin decontamination in the context of chemical exposures, integrating recent scientific findings. The paper compares dry, wet, and hybrid techniques, including improvised approaches, and ready-to-use decontamination kits, adding practical insights for emergency planning.*

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1. Introduction

Decontamination involves removal or neutralization of toxic agents from skin, equipment, and other surfaces. Knowledge of agents used and their properties allows for the adaptation of suitable decontamination methods. According to recent research, effectiveness depends primarily on the timing of the initiation of the decontamination. The lack of specific standardized procedures based on scientific research was the basis for undertaking an analysis of this issue from a theoretical perspective.

The need to conduct decontamination stems from the risk of possible failure of industrial equipment that processes, stores or transports toxic industrial chemicals (TICs), as well as the deliberate use of chemical warfare agents (CWAs) by an adversary.

Historically, there are many examples of the use of poisonous agents during armed conflicts (Black, 2016; Johnson, Larsen, and Meek, 2020; Richardt, 2008). Initially, discoveries of harmful properties of substances were the result of accidental actions; however, at the beginning of the 20th century, it became clear how great the potential was for the use of chemical weapons.

As a result, directly before the outbreak of World War I, research on the development of new compounds became deliberate, academic and industrial laboratories focused on the quantitative and qualitative development of chemical warfare agents, as well as on methods of their production and use on the battlefield. Some of the first toxic agents used in combat operations during that period were substances already employed in industry, including chlorine and phosgene (Black, 2016; Grabowski, Richardt, and Blum, 2008).

These compounds were unstable in the environment, quickly undergoing dispersion. Since 1917, sulfur mustard has been used in warfare, contaminating not only the air but also the ground and equipment. Moreover, it resulted in a relatively low mortality rate (about 5% of soldiers exposed to mustard gas died), that burdened medical services. The injuries healed slowly, with an average recovery period lasting 6-7 weeks (Black, 2016; Johnson, Larsen, and Meek, 2020; Richardt, 2008).

In the period preceding World War II, Germans developed a new group of chemical warfare agents – nerve agents (organophosphorus compounds). In 1936 tabun was discovered, in 1938 sarin, and in 1944 soman (Johnson, Larsen, and Meek, 2020;

Richardt, 2008). The first two were produced on a mass scale during the war, but were not used on the battlefield.

After World War II, the era of nuclear weapons began; nevertheless, in the 1950s a new organophosphorus compound was developed (in the United Kingdom), originally intended as a potential insecticide. It turned out to be too toxic to be used in agriculture, however, after further research, another application was found military application, as the first compound of a new class, the V agents (Black, 2016; Johnson, Larsen, and Meek, 2020).

Subsequent work to increase toxicity while minimizing the possibility of detection by standard devices was carried out since the 1960s in the USSR under the project name FOLIANT. The result of these efforts was the development of organophosphorus agents from the A series, commonly known as Novichoks (Boczkowski *et al.*, 2025).

2. Research Results and Discussion

2.1 Classification of Chemical Warfare Agents (CWAs)

When considering decontamination as a process of neutralising hazardous substances, one must primarily consider the justification for such actions. That depends mainly on the type of chemical agent used and the prevailing weather conditions. The most important property of chemical substances in this context is their persistence in the environment, that is, a measure of how long they will remain a threat. Based on this property, two groups can be distinguished: persistent and non-persistent agents (Black, 2016; ATP-3.8.1, 2010).

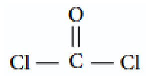
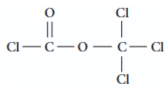
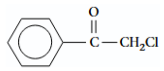
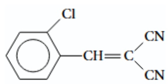
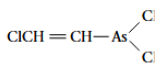
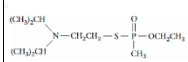
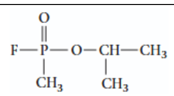
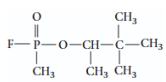
CWAs belonging to the group of non-persistent agents cause only minor or no surface contamination. When released, the resulting cloud will move with the wind, which will lead to faster dispersion and a decrease in concentration. For this reason, it can be assumed that such substances do not remain in the environment for more than an hour, however, this time depends on prevailing weather conditions.

Due to the short threat period, it is sufficient to use personal protective equipment or collective protective measures and then wait until the concentration falls below the threshold value (Black, 2016; ATP-3.8.1, 2010; Econdi *et al.*, 2024). This group includes the majority of chemical warfare agents (e.g. blood, choking and tear agents).

The second group consists of agents that can persist in the environment from several days to even weeks, depending on weather conditions. They most often occur as droplets, thereby contaminating surfaces and posing a contact hazard, at the same time they may evaporate, creating the possibility of inhalation exposure (Black, 2016; ATP-3.8.1, 2010; Picard *et al.*, 2019). CWAs with such properties are primarily blister agents (e.g. sulfur mustard, nitrogen mustard, lewisite) and VX.

Consequently, decontamination should be considered in the context of minimizing the hazard posed by persistent agents.

Table 1. *Persistency of selected CWAs.*

Class	Name	Chemical structure	Persistency
Blood agents	Hydrogen Cyanide	N≡C—H	Short; in suitable conditions, vapor may remain in jungle and forest areas for some time.
	Cyanogen Chloride	N≡C—Cl	Short; due to its high volatility and the gas phase quickly dissipates in air.
Choking agents	Phosgene		Short; about 30 min in summer; approximately 3 h at –20˚C.
	Diphosgene		About 30 min to 3 h in summer; 10–12 h in winter.
	Chlorine	Cl_2	Short; under stable conditions with calm or light winds, vapor can persist in low areas.
Tear agents	Chloroacetophenone		Short, as the compounds are carried as an aerosol.
	CS		It varies with the level of contamination and the form of CS; CS aerosol typically leaves little residual hazard.
Blister agents	Sulfur mustard	$Cl—CH_2CH_2—S—CH_2CH_2—Cl$	Under average weather, heavy liquid splashes can remain at casualty-producing levels for 1–2 days or longer, and for a week to months in very cold conditions.
	Lewisite (L-1)		Slightly shorter than sulfur mustard; extremely short duration in humid conditions
Nerve agents	VX		Persistence depends on both the munitions employed and prevailing weather. Heavily splashed liquid persists for long periods of time under average weather conditions. In extreme cold, VX may remain for months.
	Sarin		Evaporates at approximately the same rate as water; persistence varies with the munitions used and the weather.
	Soman		It varies with the munitions employed and the weather. Heavy liquid splashes last 1–2 days in typical conditions. Adding thickeners can greatly extend persistence.

Source: *Prepared based on Hoenig (2007).*

2.2 Decontamination – General

Decontamination involves the complete removal of contamination or the reduction of a toxic agent's concentration to levels that do not pose a threat to the human body. The process may involve physical removal or chemical neutralization of CBRN agents present on people, vehicles, equipment and in the environment. In many cases, methods combining both approaches are used (Altmann and Richardt, 2008; Brame *et al.*, 2016; Titus *et al.*, 2019).

The development and potential use of chemical weapons necessitated the parallel developments of methods for protection and mitigation their effects. Significant progress in this field was achieved during World War I.

Initially, toxic agents were used in the form of gases or vapors, which were non-persistent in the environment, did not cause long-term contamination, and consequently did not require decontamination (Yang, Baker, and Ward, 1992; Fitzgerald, 2008).

The requirement for active decontamination dates back to the introduction of shells and mortar rounds filled with mustard agent into warfare. Soldiers exposed to it had to bathe in hot water and use soap to remove the agent from their skin. Portable shower units staffed by trained medical personnel helped to minimize the debilitating effects. These consisted of a bathing cart equipped with a hot water boiler and several foldable shower heads (Fitzgerald, 2008).

At that time, it was recommended to first wash the contaminated skin with kerosene or gasoline, and then wash with water and soap. The timing of this procedure was particularly important. Studies estimated that sulfur mustard must be removed within three minutes to limit its toxic effects on human tissue. Because exposure to even minute quantities of sulfur mustard can result in eye injuries, the victims' eyes were rinsed immediately to reduce (Fitzgerald, 2008).

The purpose of decontamination is to completely prevent or reduce the penetration of substances through the skin that could pose a health risk. An effective skin decontamination system should (Magnano, Rui and Larese Filon, 2021):

- decrease the amount of toxic agents absorbed through the skin;
- significantly delay absorption;
- improve the ability to neutralize toxic agents deposited on the skin.

Time is a crucial factor in the decontamination process, which should be carried out as quickly as possible to prevent further exposure and minimize damage. In case of direct skin exposure, it is recommended to remove the toxic agent immediately (within one minute) using water, soap, improvised absorbents or specialized decontamination agents (Karakurt and Bilgiseven, 2024).

Short reaction time is essential in cases of exposure to liquid nerve or blister agents, which are quickly absorbed through the skin, and within minutes of exposure cause cellular damage. It is estimated that the amount of toxic agent can be reduced by up to 80% by removing clothing, as it can absorb part of the toxic substances in liquid and vapor form (Baş and Karakurt, 2024).

This practice is widely considered justified and forms the basis for many official guidelines on decontamination and CBRN response (Titus *et al.*, 2019). If clothing is chemically contaminated, it should be removed carefully to prevent skin contact with the agent and to avoid excessive release of the substance absorbed by the fabric. In some cases, cutting off the contaminated clothing may be necessary (Karakurt and Bilgiseven, 2024).

Decontamination not only limits potential exposure (e.g., by reducing the absorption of toxic substances through the skin) but also decreases the uncontrolled spread of contamination to initially unexposed individuals, responders, equipment, and medical facilities (Collins *et al.*, 2021).

Decontamination methods can be divided into wet and dry types.

2.2.1 Wet decontamination

Wet decontamination involves washing a contaminated surface with plain water or soapy water to remove the toxic agent. In many cases, a shower is the most recommended method. However, it should not be used for substances that react with water or in low temperatures, to avoid hypothermia (Titus *et al.*, 2019).

It is believed that wet methods using large amounts of water act primarily by physically removing or diluting the toxic agent, but also by reducing the rate of chemical reactions, decreasing tissue metabolism and inflammation, and restoring natural pH of the skin (Burli *et al.*, 2021).

The ability of water to dissolve poisonous agents and break them down through hydrolysis can be improved by adding surfactants. These substances have the capacity to dissolve lipophilic compounds by forming micelles that absorb lipophilic substances, which are then washed out by water (Altmann and Richardt, 2008; Burli *et al.*, 2021).

Soap and water (especially hot water) also have some ability to neutralize chemical agents through the chemical process of slow hydrolysis. However, this process is limited due to the generally low solubility and slow diffusion rate of toxic substances in water (Fatah *et al.*, 2007).

The longer a chemical substance remains on the skin, the more likely its molecules are to be absorbed. If a toxic agent entered the body, removing or neutralizing it becomes more difficult, as most decontamination methods work only on the skin surface. Therefore, to limit absorption and increase the effectiveness of decontamination, the process should start as soon as possible. This is confirmed by some in vivo studies comparing immediate and delayed decontamination, which established that with delayed initiation, wet methods may have limited effectiveness and may no longer be able to sufficiently remove toxins from skin (Burli *et al.*, 2021).

Nevertheless, water as a decontaminant offers a number of benefits, such as: relatively low cost, availability in large quantities, and, most importantly, harmlessness to humans and the environment (Altmann and Richardt, 2008). On the other hand, disadvantages include: the risk of hypothermia when used at low temperatures, and low reactivity towards most chemical warfare agents (Titus *et al.*, 2019; Thors *et al.*, 2024).

Additionally, it should be noted that water-based decontamination generates large amount of contaminated wastewater, which requires proper disposal. The study by Medina *et al.* (2025) describes mobile systems for collecting and purifying post-contamination water. These systems help to reduce the risk of long-term environmental contamination and significantly lower waste disposal costs.

2.2.2 Wash-in effect

Increasingly, literature reports that washing skin with water and soap enhance the absorption of chemical substances through the so-called “wash-in” effect. Unfortunately, this process has not been sufficiently characterized. Skin washing may increase dermal uptake of toxic substances due to the degradation of the epidermal barrier properties.

A literature review indicates that this effect has been observed mainly in in vitro studies and involves mechanisms such as: hydration of the outermost layer of the skin, action of surfactants (e.g. soap), physical factors (friction, increased contact area), changes in skin pH, and physicochemical properties of toxic substances. This effect may increase the risk of complications; therefore, it is recommended to use dry decontamination first, followed by washing with water and soap (Magnano, Rui, and Larese Filon, 2021).

Research conducted by Forsberg *et al.* (2020) aimed to evaluate the effectiveness of removing toxic substances from human skin using water and soapy water. They analyzed both methods and the impact of decontamination initiation timing. It was found that effectiveness depended mainly on time – the best results were achieved when the process began within five minutes of exposure.

Additionally, for none of the tested substances a significantly greater decontamination effectiveness was observed when using water with soap compared to water alone. However, in some cases, especially when soap was used, the previously mentioned "wash-in" effect was observed, meaning an increase in skin permeability due to washing.

The study described by Thors *et al.* (2021) showed that washing contaminated skin with soapy water reduced the amount of VX in the upper layers of stratum corneum, but increased the amount of the skin-penetrating agent compared to the non-decontaminated control group. This finding strongly confirms the occurrence of the "wash-in" effect.

2.2.3 Dry decontamination

Dry decontamination is defined as "the local application of absorbent materials to remove toxic substances from the skin surface". This method was developed to enable immediate self-decontamination by effected personnel prior to arrival of emergency responders (Collins *et al.*, 2021).

Dry decontamination agents are absorbent materials used to soak up toxic substances. These may include commercial off-the-shelf (COTS), such as Fuller's earth or improvised decontamination materials, such as paper towels, cloths, baking powder or talc (Titus *et al.*, 2019).

Some armies are equipped with Fuller's earth, a solid sorbent, a material characterized by its ability to absorb chemical substances. It mainly consists of aluminum oxide, silica, iron oxide, lime, magnesium oxide, and water in variable proportions and is generally classified as a sedimentary clay – a common term for a range of fine-grained, earthy materials that become plastic when mixed with water (Altmann and Richardt, 2008).

The main advantage of using Fuller's earth, particularly in cases of short exposure times, is the rapid and complete physical removal of the agent, even in large quantities, whereas complete chemical neutralization may take more time (Dachir *et al.*, 2021).

When solid absorbent materials such as Fuller's earth, soil or diatomaceous earth are used, the toxic agent usually does not undergo any chemical change – for example, petroleum products are easily absorbed, but their properties are not altered.

As a result, the sorbent material becomes toxic, must be collected and disposed of. Proper precautions must be taken before during the collection process, as fine dust particles may be inhaled or may come into contact with exposed skin. Due to this fact, there is a possibility of secondary contamination. It should be noted that it is not possible to remove the poisonous substance that has already penetrated into the deeper layers of skin (Magnano, Rui, and Larese Filon, 2021).

Another example of a sorbent used by some NATO countries is the M291 Skin Decontamination Kit, which has the ability not only to absorb but also to neutralize chemical substances (Capoun and Krykorkova, 2021).

The M291 SDK is a compact, wallet-style pouch that holds six single-use packets designed to remove liquid chemical agents from skin. Each packet contains a nonwoven pad impregnated with two active materials: activated carbon to absorb organic agents and Ambergard XE-555, a reactive ion-exchange resin.

The cotton pad provides structure so it can be rubbed over exposed areas, including face and areas around wounds, delivering a one-step, non-toxic, non-irritating application.

As the pad is scrubbed across contaminated skin, chemical agents are rapidly captured within the carbon and resin particles; acidic and basic groups in the resin then promote gradual detoxification of the trapped agents. A residue of black powder from the pad may remain on the skin after application.

For best effectiveness, excess powder should be brushed off after treatment, since the resin binds agents first and neutralizes them slowly, and residual powder can still contain active or only partially inactivated agent (National Urban Security Technology Laboratory (NUSTL), 2017; Clarkson and Gordon, 2020).

Similar properties are exhibited by $TiO2$, MgO, CaO, ZnO, $Al2O3$, $MnO2$, and transition metal-containing nanoporous silica, which are considered reactive sorbents due to their dual function of adsorbing and destroying toxic agents (Magnano, Rui, and Larese Filon, 2021; Gonciarz *et al.*, 2025).

The study by Sellik *et al.* (2017) demonstrated that an MgO-based decontaminants can effectively neutralize toxic compounds. Meanwhile, research by Denet *et al.* (2020) confirms that metal oxides (CeO_2, TiO_2, and MgO) are effective in the degradation of paraoxon (a VX simulant). In less than two hours, the toxic agent was completely degraded.

Kassouf *et al.* (2017) evaluated a range of absorbent materials that could be used as improvised dry decontamination agents. Using simulants of sulfur mustard, soman, and some toxic industrial chemicals (parathion, phorate, and potassium cyanide), the authors demonstrated that absorbent materials readily available to first responders, such as paper towels, were effective in removing liquid toxic agents from pig skin ex vivo.

This method of dry decontamination proved to be more effective than improvised wet decontamination for all tested substances except potassium cyanide. Therefore, it can be concluded that the use of water is necessary in case of contamination with toxic agents in solid form.

In summary, dry decontamination has several key advantages: it can be performed almost immediately after exposure, many widely available materials can be used to absorb toxic agents and most importantly, exposed individuals can carry out the decontamination kits themselves.

2.2.4 Dry/wet decontamination

Thors *et al.* (2023) conducted a study aimed at assessing the effectiveness of various skin decontamination strategies, particularly the impact of adding dry methods prior to wet decontamination.

They used four different chemicals with diverse physicochemical properties: 2-butoxyethanol (2-BuEtOH), tabun, VX, and a sulfur mustard simulant - methyl salicylate (MeS). Four decontamination procedures corresponding to different scenarios were evaluated: 1) immediate wet decontamination; 2) immediate dry and wet decontamination; 3) immediate dry decontamination followed by delayed wet decontamination; 4) delayed wet decontamination.

Immediate decontamination was initiated 5 minutes after exposure and involved approximately 30 seconds of wiping with Wettex Classic cloths. For wet methods, a 2% soap solution in water was used. Delayed decontamination was performed 30 minutes after exposure. Experiments were conducted using an in vitro skin penetration model. The procedure combining dry and wet decontamination after exposure to MeS proved to be more effective compared to wet decontamination alone.

However, the benefit of the dry phase was not confirmed for other chemical substances, preventing the procedure from being considered universally effective. Immediate removal of tabun by dry methods was not more effective than wet decontamination alone. After exposure to 2-BuEtOH, immediate wet decontamination turned out to be the most effective procedure.

Decontamination after exposure to VX resulted in a significantly increased skin penetration rate compared to the control group for all tested procedures, confirming the occurrence of the previously mentioned "wash-in" effect.

A study conducted by Southworth *et al.* (2020), evaluated the effectiveness of improvised skin decontamination methods – dry, wet and a combination of both. Methyl salicylate was used as a simulant of CWAs. It was found that the best results were obtained by applying both methods consecutively; however, it was also noted that no method completely removed the simulated agent, especially from areas difficult to reach.

2.2.5 Reactive Skin Decontamination Lotion (RSDL)

Commercial decontamination kits are a key protection element component in toxic agent contamination scenarios. They are designed to enable immediate and effective neutralization, as well as the removal of chemical agents from skin, equipment, and other surfaces. Their use is essential both in military operations and industrial accident responses. Among many kits, the Reactive Skin Decontamination Lotion (RSDL) stands out because of its high effectiveness. It employs both physical and chemical methods of neutralization.

It comprises of diacetylmonoxime (DAM), a reactive oxime, along with DAM potassium salt of to neutralize chemical agents and polyethylene glycol monomethyl ether for absorbtion. Tests have shown high effectiveness against organophosphorus agents and sulfur mustard (Titus *et al.*, 2019; Capoun and Krykorkova, 2021).

The application procedure involves wiping the skin area exposed to the toxic agent with a lotion-impregnated sponge (Baş and Karakurt, 2024). The lotion should be applied within three minutes of contamination and gently rubbed into the skin for two minutes, with residues washed off afterwards (Magnano, Rui, and Larese Filon, 2021).

Moreover, DAM is absorbed through the skin. This penetration is an important factor determining effectiveness, as it allows for the deactivation of agents that have already absorbed below the skin before they enter the bloodstream (Dachir *et al.*, 2021).

The decontamination of soman on guinea pig skin was studied by comparing the effectiveness of a 0.5% sodium hypochlorite solution, a 1% soap solution in water, Reactive Skin Decontamination Lotion (RSDL), and the M291 Skin Decontamination Kit. Each decontamination procedure was performed two minutes after exposure.

The best results were obtained using RSDL; however, subsequent trials with delayed decontamination showed a significant decrease in its effectiveness. The other tested agents demonstrated similar levels of effectiveness, which were several times lower than that of RSDL (Titus *et al.*, 2019).

Another study reported that both Fuller's earth and RSDL are the most effective decontamination agents against blister and nerve agents, organophosphorus pesticides, and other toxic substances. It was found that the removal of toxic compounds is quick and thorough, and that high effectiveness is maintained even when decontamination is delayed (Dachir *et al.*, 2021).

The ability of the RSDL kit to neutralize the contact toxicity caused by Novichok-type agents (A-230, A-232, A-234) was also evaluated in both in vitro and in vivo studies. In vitro tests showed that all three compounds were neutralized by RSDL, albeit at different rates. In a large excess of RSDL, the half-life of A-234 was 36 minutes, making it the most persistent compared to A-230 (<5 minutes) and A-232 (18 minutes).

In the context of reports on the degradation of classical compounds, e.g. VX (2.5 minutes), the decomposition kinetics — especially of A-234 — appear much less favorable. It should be noted that this study did not identify the decomposition products, so it remains unclear to what extent RSDL actually neutralizes a given agent (Cornelissen *et al.*, 2024).

The penetration of the toxic agent and the effect of decontamination on hair have also been studied. Although hair protects the scalp, some chemical warfare agents penetrate relatively quickly through hair sebum into follicles, from where they can be absorbed into the body. In vitro studies on hair decontamination after VX and sulfur mustard simulant exposure showed that showering alone was the least effective method.

Applying Fuller's earth or Reactive Skin Decontamination Lotion (RSDL) within 45 minutes of exposure, before showering, significantly improved the removal and neutralization of toxic agents. Nevertheless, VX and the simulated agents remained in the hair after decontamination (up to 27% and 57% of the initial amount, respectively) (Collins *et al.*, 2021).

3. Conclusions

Although skin decontamination has been studied since World War I, an effective method that works regardless of the type of toxic agent and conditions has not yet been developed. Recent research indicates that in case of use of chemical warfare agents or contamination with a toxic industrial substances, the most critical factor influencing the effectiveness of decontamination is the timing of its initiation. It is crucial to take action within the first few minutes after exposure.

This is particularly important in mass-casualty incidents. This criterion necessitates the preparation of operational procedures, making it possible to mitigate the effects among directly exposed individuals as well as medical services at risk of secondary contamination.

The positive aspect is that in the initial phase we can use readily available materials, such as paper towels. In some cases, it may be necessary to carry out decontamination using water available at the scene to assist all exposed personnel.

During the planning of decontamination, factors such as the type of contamination, feasibility, effectiveness, and costs should be considered, as they will allow for the selection of a specific method. The decontaminant should have a broad spectrum of action, meaning the ability to neutralize all possible chemical warfare agents. The ease of preparation and application is also important. Considering the need for use on the skin, the agent should not be irritating and should not affect chemical detectors used to verify the presence of toxic agents.

An burning issue in research on the effectiveness of decontamination methods is the lack of standardization. Parameters, such as the type and amount of toxic substances or simulating agents, the method of application, the timing of decontamination, the combination of different techniques and even the temperature have a significant impact on results, yet they remain variable.

Another inconsistency arises from using different animal models —factors that may affect skin penetration and thus decontamination, differ between species. Each animal has a different thickness of the stratum corneum, fur thickness, and the number and composition of glands. Studies are also conducted using different methods—in vitro and in vivo.

All these factors make it difficult to compare results obtained from different studies, often resulting in comparisons being possible only within a single study. No in vivo animal model can be fully representative of humans. Therefore, data collected from studies on in vivo animal models can be extrapolated to generalize about in vivo effects in humans, but they should never be considered fully conclusive.

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