REUE | Review Article

Skin and eye decontamination after exposure to chemical agents

Santiago Nogué Xarau[1], Montserrat Amigó Tadín[2]

OBJECTIVE. Emergency Department visits due to skin or ocular exposure to chemical agents (CAs) are now part of everyday life. The aim of this review is to describe the evidence supporting the practice of skin and ocular decontamination following these incidents and identify the most effective decontamination agent or method in terms of toxicity reduction and absence of side effects.

MATERIAL AND METHODS. We followed the general guidelines of the PRISMA standard. A document search was conducted across 2 databases (PubMed and ISI Web of Knowledge) using the following keywords: ("skin decontamination" OR "ocular decontamination") AND ("chemical exposure" OR "chemical agents"). In a second phase, a more specific search was conducted to identify documents referencing the use of diphoterine or hexafluorine, with the following keywords : ("Diphoterine" OR "Hexafluorine" AND "skin decontamination" OR "ocular decontamination" OR "chemical exposure" OR "chemical agents"). The same strategy was applied using the search engines of 2 Spanish journals devoted to emergency medicine (EMERGENCIAS and REUE), introducing the same keywords in Spanish.

RESULTS. Initially, a total of 392 documents were identified, but after applying the exclusion criteria only 44 documents were eventually evaluated. The removal of contaminated clothing and the immediate initiation of decontamination are the most universally accepted measures. Solid CAs are best decontaminated by scraping or brushing. For liquid forms, water is the decontaminant of choice. Lipid-soluble agents are better decontaminated with water and soap. After exposure to chemical weapons (CWs), initial measures should include the removal of clothing and dry decontamination. Although low-quality evidence studies surround specific decontaminants, such as diphoterine or hexafluorine, some show more favorable results vs water.

CONCLUSIONS. Early decontamination remains the key factor in reducing injuries after chemical exposure. Dry decontamination is highly effective with solid products and CWs. For liquid CAs, water or water with soap are the most effective and accessible options.

Keywords: Skin decontamination, Ocular decontamination, Chemical agent, Chemical burn, Chemical weapon.

Descontaminación cutánea y ocular en las exposiciones a productos químicos

OBJETIVO. Las consultas a urgencias por una exposición cutánea u ocular a productos químicos (PQ) son una realidad cotidiana. El objetivo de esta revisión es describir la evidencia sobre la que se basa la descontaminación cutánea y ocular en estas incidencias e identificar el agente o método de descontaminación que hayan mostrado más eficacia en términos de reducción de toxicidad y ausencia de efectos secundarios.

MATERIAL Y MÉTODOS. Se ha seguido la norma PRISMA. Se realizó una búsqueda de documentos en dos bases de datos, PubMed y ISI Web of Knowledge, con la siguiente expresión: ("skin decontamination" OR "ocular decontamination") AND ("chemical exposure" OR "chemical agents"). En una segunda fase se realizó otra búsqueda más específica con el fin de identificar documentos referentes al uso de diphoterine o hexafluorine, y para lo que se introdujo la expresión: ("Diphoterine" OR "Hexafluorine" AND "skin decontamination" OR "ocular decontamination" OR "chemical exposure" OR "chemical agents"). La misma estrategia se utilizó con el buscador de dos revistas españolas del ámbito de la medicina de Urgencias, Emergencias y Revista Española de Urgencias y Emergencias, introduciendo las mismas palabras clave en español.

RESULTADOS. Se identificaron inicialmente 392 documentos. Tras aplicar los criterios de exclusión se evaluaron 44 de ellos. La retirada de la ropa contaminada y el inicio inmediato de la descontaminación son las medidas universalmente más aceptadas. Los PQ en forma sólida se descontaminan mejor con raspado o cepillado. En las formas líquidas, el agua es el descontaminante de elección. Los agentes liposolubles se descontaminan mejor con agua y jabón. Tras una exposición a armas químicas (AQ), las maniobras iniciales han de ser la retirada de la ropa y la descontaminación en seco. Descontaminantes específicos como diphoterine o hexafluorine tienen estudios de baja evidencia, aunque algunos muestran resultados más favorables que el uso de agua.

CONCLUSIONES. La descontaminación precoz sigue siendo el factor determinante en la reducción de lesiones tras una exposición química. La descontaminación seca es muy eficaz con productos sólidos y AQ. Con PQ líquidos, el agua o el agua con jabón son las opciones más efectivas y accesibles.

Palabras clave: Descontaminación cutánea. Descontaminación ocular. Producto químico. Quemadura química. Arma química.

Author Affiliations: [1]Fundación Española de Toxicología Clínica, Spain. [2]Área de Urgencias, Hospital Clínic de Barcelona, Spain.
Corresponding Author: Santiago Nogué Xarau. Fundación Española de Toxicología Clínica, Spain.
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Introduction

Exposure to chemical agents (CPs) is a risk in diverse settings, including industrial, agricultural, and domestic environments, and a frequent reason for consultation in emergency departments (EDs).[1,2] According to the Spanish Toxicovigilance Program, which collects data on patients attended in EDs for chemical exposure, ocular or cutaneous contact accounts for 9.64% of the routes of exposure to these agents.[3]

The consequences of such exposures can be significant. Locally, depending on the physicochemical characteristics of the CP, outcomes may range from mild and transient irritation (dermatitis, keratoconjunctivitis) to varying degrees of burns, with their associated signs and symptoms. On the skin, CPs can cause deep burns and leave irreversible sequelae such as permanent scarring, while ocular exposures may induce severe corneal injury with reduced visual acuity or even ocular perforation resulting in irreversible vision loss.[4] Systemically, depending on their liposolubility, CPs may be absorbed through the skin and cause toxicity in multiple organs and systems. Furthermore, some of these agents can chelate ions such as calcium and magnesium, leading to severe electrolyte disturbances with cardiovascular manifestations that may progress to cardiac arrest and death.[5]

As a general rule, cutaneous and/or ocular decontamination (COD) is accepted as effective in minimizing harm in exposed individuals. However, controversy exists regarding the time window in which decontamination remains useful, and particularly, regarding which decontaminants and application methods are most effective and safe in reducing CP-induced damage. Several methods have been employed to mitigate the consequences of these exposures, including washing with water or water and soap, irrigation with saline solutions, or the use of specific decontaminants such as polyethylene glycol for phenol exposures[6] or diphoterine following corrosive contact,[7] as well as adsorbent substances like Fuller's earth.[8] The effectiveness of these methods may vary considerably depending on the characteristics of the CP, contact dose, exposure duration, time elapsed until therapeutic intervention, and the decontaminant used. Although multiple guidelines and protocols for COD exist, the available scientific evidence is often of low quality, and notable controversy persists regarding the most effective method(s).

The objective of this review is to describe the scientific evidence supporting COD following CP exposure, identify the agents demonstrated to be most effective and safe in terms of reducing toxicity, shortening recovery time, and avoiding adverse effects, and to establish the optimal method of application.

Materials and methods

This review was conducted following the general guidelines of the PRISMA statement. Between June and September 2024, a literature search was performed in PubMed and ISI Web of Knowledge databases using the following search expression: ("skin decontamination"[Title/Abstract] OR "ocular decontamination"[Title/Abstract]) AND ("chemical exposure"[Title/Abstract] OR "chemical agents"[Title/Abstract]). In a second phase, a more specific search was conducted to locate documents referring to the use of diphoterine or hexafluorine in clinical practice, as these products are considered specific for cutaneous or ocular exposure to corrosives and their efficacy remains controversial. For this, the following search expression was used in the same databases: ("Diphoterine"[Title/Abstract] OR "Hexafluorine"[Title/Abstract]) AND ("skin decontamination"[Title/Abstract] OR "ocular decontamination"[Title/Abstract] OR "chemical exposure"[Title/Abstract] OR "chemical agents"[Title/Abstract]). The same strategy was applied to two Spanish emergency medicine journals (Emergencias and Revista Española de Urgencias y Emergencias), entering the same keywords in Spanish. The document search was limited to those published in the last 25 years (2000–2024).

Excluded documents included those referring solely to in vitro or laboratory animal decontamination, cutaneous or ocular contamination by biological weapons (eg, botulinum toxin, ricin), viruses, or bacteria, as well as any document not addressing COD for CP exposure. Also excluded were letters to the editor, research projects without results, documents not freely accessible in their respective journals or publishers, documents unavailable in the 3 consulted electronic libraries (University of Barcelona, Canary Islands Health Service, Balearic Library), and full-texts in languages other than Spanish, English, or French.

For the selected documents, the following were evaluated: study population (number of patients, circumstances of contamination), intervention details (type of decontaminant), outcomes (subjective improvement, symptom duration, sequelae, mortality), adverse effects attributable to the decontaminant, study conclusions, level of evidence, grade of recommendation, and Conflicts of interest declaration.

The level of evidence of each study was assessed according to the Scottish Intercollegiate Guidelines Network (SIGN) criteria,[9] and the treatment recommendation grade was based on the U.S. Preventive Services Task Force (USPSTF) system[10] (Table 1). Article categorizations were agreed upon by the authors of this review, as was the rest of the methodology.

Results

The search strategy identified a total of 392 documents (Figure 1), of which 117 were located through PubMed, 267 through ISI Web of Knowledge, 7 through the *Emergencias* search engine, and 1 through the *Revista Española de Urgencias y Emergencias* search engine. A total of 319 of these documents were excluded for failing to meet at least 1 inclusion criterion. The most frequent exclusion causes were in vitro studies (n = 169), studies in animals (n = 66), those addressing nonchemical contamination (n = 38), research projects without results (n = 7), letters to the editor (n = 13), studies related to gastrointestinal decontamination (n = 3), or other reasons, such as

Table 1. Classification of the level of scientific evidence of the document and the grade of recommendation of the proposed treatment

Level of evidence	
1++	High-quality meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs with a very low risk of bias.
1+	Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias.
1-	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias.
2++	High-quality systematic reviews of cohort or case-control studies, or high-quality cohort or case-control studies with very low risk of confounding, bias, or chance, and a high probability that the relationship is causal.
2+	Well-conducted cohort or case-control studies with low risk of confounding, bias, or chance, and a moderate probability that the relationship is causal.
2-	Cohort or case-control studies with a high risk of confounding, bias, or chance, and a significant probability that the relationship is not causal.
3	Non-analytical studies (clinical observations and case series).
4	Expert opinions. Non-systematic reviews.
Grade of recommendation	
A	Highly recommended (good evidence that the intervention is effective and the benefits clearly outweigh the harms).
B	Recommended (at least moderate evidence that the intervention is effective and the benefits outweigh the harms).
C	Neither recommended nor discouraged (at least moderate evidence that the intervention is effective, but the benefits are very similar to the harms, so a general recommendation cannot be justified).
D	Not recommended (at least moderate evidence that the intervention is ineffective or that the harms outweigh the benefits).
E	Insufficient, poor-quality, or contradictory evidence, and the balance between benefits and harms cannot be determined.
	Conflicts of interest that may affect the independence of the authors.

journals inaccessible through the electronic platforms used (n = 2), full text in a language outside the inclusion criteria (n = 6), or other causes (n = 15). Seventy-three documents remained. Of these, 29 were duplicates and were excluded, leaving a final total of 44 analyzed documents: 7 systematic reviews, 16 nonsystematic reviews, 12 case series, 6 prospective cohort studies, and 3 single case reports.

The 44 included documents (Table 2) consistently emphasize that, following cutaneous exposure, contaminated clothing should be removed immediately and decontamination initiated as soon as possible, ideally within 3 minutes. Beyond this, strategies diverge. For solid products, there is agreement on starting with "dry decontamination," that is, mechanically removing the CP using a wooden spatula, a soft brush, or similar, followed by absorption or adsorption with towels, gauze, paper rolls, or incontinence pads.

In chemical weapon (CW) incidents, the agent is often a "gas" impregnating the skin. A recent large-scale study involving healthy and disabled volunteers demonstrated that, in mass-casualty settings, the most effective initial prehospital maneuver was patient disrobing followed by "dry decontamination" with rolled paper, towels, or pads. The next step, once available, was "wet decontamination" using a ladder-pipe system: two fire trucks parked parallel created a central corridor through which a high-volume, low-pressure water mist was sprayed, allowing ambulatory contaminated individuals to pass through for ~15 seconds, while a ladder truck sprayed water from above. The third and final step was "technical decontamination," in which the patient was sprayed with lukewarm water through 6 nozzles for 90 seconds while wiped with a baby shampoo–soaked cloth. This three-step sequence achieved maximal decontamination efficacy and was particularly important in mass-casualty incidents, where firefighters and emergency medical services play a crucial role. In all cases, personnel assisting with decontamination must use personal protective equipment (PPE) appropriate to the chemical risk. These recommendations reflect federal guidelines in the United States for mass victim decontamination during the initial response to a chemical incident.[11] Other authors propose simplifying the process, after clothing removal, to decontamination with water and soap for at least 3–5 minutes, which may also be appropriate for patients who arrive spontaneously at hospitals.

When the CP contacting the skin is liquid, and especially if it has caustic properties, abundant water irrigation applied immediately, or at least within 3 minutes, is essential to attempt to prevent injury and sequelae. With noncorrosive CPs, copious immediate water irrigation is also effective, and the more liposoluble the agent, the greater the importance of soap in this process. Dry decontamination is not recommended for corrosives, biological contaminants, or radioactive agents.

In cases of ocular contamination, immediate action is critical given the high risk of visual acuity compromise. Tap water is the most accessible and economical decontaminant, and multiple studies agree that it is the initial maneuver of choice. If present, contact lenses should be removed. Provided it does not delay initiation, some authors advocate for the use of 0.9% NaCl solution, Ringer's lactate, or balanced saline solution, as these may be better tolerated and/or contribute to reducing pain and normalizing pH; however, the methodological quality of available studies does not allow firm recommendations. In all cases, ocular decontamination should be continued for at least 20 minutes.

To enhance the decontamination efficacy profile, several specific agents have been proposed, such as diphoterine, hexafluorine, and reactive skin decontamination lotion (RSDL). Of the documents included, 23 referenced diphoterine, 8 of which disclosed conflicts of interest. Of the remaining 15, most were of low evidence level (grade 3 or 4). In a series of 156 cases, patients exposed to caustic products or self-defense sprays who received diphoterine had significantly greater initial symptom improvement compared with water, although this did not affect subsequent clinical course.

Five systematic reviews included evaluations of diphoterine. One concluded that, given the absence of adverse effects and probable greater efficacy compared with water, diphoterine should be used if immediately available. Another review found it more effective than water in improving healing time, preventing sequelae, and controlling chemical burn pain, though it acknowledged the poor

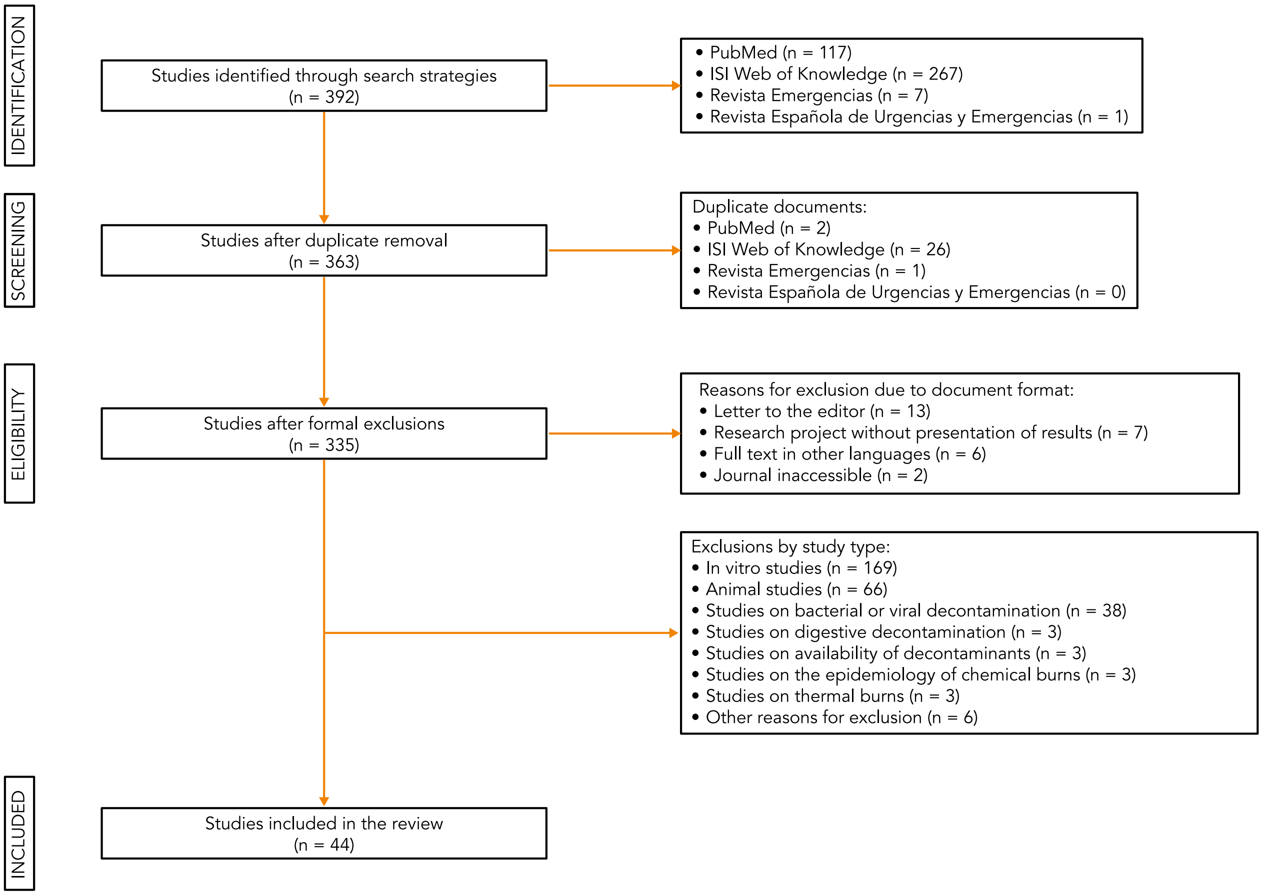

Figure 1. Flow diagram of the document selection process.

methodological quality of available human studies. A review focused on ocular decontamination found no advantage of diphoterine over water. Another review reported no difference between diphoterine and water in terms of chemical burn depth, but diphoterine appeared associated with less pain. Finally, another review recognized a potential role for diphoterine in workplaces where chemical burns are frequent, as it may aid recovery. No publication described adverse effects of diphoterine.

For hexafluorine, proposed for hydrofluoric acid contamination, 4 documents were identified: half disclosed conflicts of interest, and the remaining 2 were of low evidence (grade 4). Although both reported favorable effects, no definitive conclusions could be drawn. No adverse effects have been reported.

RSDL lotion has been considered for its decontamination utility in military settings involving CW incidents. It has been evaluated in 2 nonsystematic reviews, 1 of which confirmed its indication for this scenario due to superior efficacy compared with water, bleach, or dry adsorbents.

Discussion

Contamination of the skin and eyes by CPs is highly heterogeneous because the precipitating circumstances (domestic or occupational accidents, suicide attempts, criminal acts, terrorism with CWs) and the agents involved (household or industrial products, agricultural chemicals, etc.) vary widely. Clinical consequences are likewise diverse and depend chiefly on the physicochemical properties of the agent (especially pH and oxidizing capacity) and on the amount and concentration of the CP, ranging from mild local irritation to deep burns, with the added possibility of systemic effects.[12,13]

This breadth of CP exposures yields a wide spectrum of contamination scenarios, making it unlikely that a single "universal decontaminant" or "single decontamination method" exists—an observation borne out by the results of this review. Consequently, to maximize decontamination efficacy, COD must be tailored to the specifics of each exposure, selecting the most appropriate option from those discussed below.

Several COD principles are consistent across sources. First, decontamination is the initial, necessary intervention for exposures to CPs, biologic agents, or radioactive materials. Second, personnel participating in decontamination must use chemical-risk–appropriate PPE, because any contaminated patient is, in turn, a contamination source; secondary contamination events are well documented.[14]

For cutaneous contamination, there is unanimous agreement that the first action should be removal of contaminated clothing, because clothing poses risk to the patient, decontamination personnel, and the environment. Garments should not be pulled, torn, or ripped; instead, they should be cut off to avoid dispersing the CP. Re-

Table 2. Characteristics of the studies included in the review

Author (year)	Study type	Target population	N/IS	CP / Exposure route	Decontaminant evaluated	Results	LE	GR	Comments
Alexander (2018)[33]	Systematic review	NA	13 studies	Various CPs. Exposure to skin and eyes.	Diphoterine	Some clinical studies show fewer lesions, fewer symptoms, greater pain reduction, and faster pH normalization with diphoterine vs. water or saline.	2++	B	No evidence of adverse effects. Likely more effective than water; if available immediately, diphoterine should be used.
Amigó (2016)[34]	Case series	Assaults with defense sprays	15 patients	Defense sprays, cutaneous and ocular exposure	Water vs. diphoterine	Symptomatic improvement with diphoterine.	3	C	Study design does not allow concluding diphoterine superior to water.
Amigó (2024)[35]	Case series	Domestic and occupational accidents, and assaults	156 patients	Various CPs, cutaneous and ocular exposure	Water vs. diphoterine	In caustic exposures or defense sprays, significant improvement in initial symptoms with diphoterine vs. water.	3	B	Use of diphoterine has no impact on hospitalization or sequelae.
Amlôt (2017)[36]	Prospective cohort	Healthy volunteers	20 volunteers	Methyl salicylate (simulated CW), cutaneous exposure	DD (absorbent paper roll vs. incontinence pads)	Rapid evacuation, undressing, and decontamination are the most effective actions against CWs. Press-and-blot DD is most effective.	2+	B	A guideline with instructions improves effectiveness. DD is not recommended for caustics, biological or radiological contamination.
Atley (2015)[37]	Non-systematic review	NA	NA	Hydrofluoric acid, ocular exposure	Hexafluorine	Some case reports with favorable evolution suggest efficacy of hexafluorine.	4	C	EDs could benefit from hexafluorine availability.
Brent (2013)[38]	Non-systematic review	NA	NA	Various CPs, dermal exposure	Water	Water is the best decontaminant.	4	B	Demonstrated efficacy in clinical trials, widely available, economical.
Chai (2022)[39]	Systematic review	Domestic and occupational accidents	14 documents	Various CPs, cutaneous exposure	Various methods, including diphoterine	Evidence supports early irrigation with cold water to reduce hospital stay and scar formation.	2++	B	Diphoterine should be readily available at workplaces with potential for chemical burns.
Chan (2013)[40]	Non-systematic review	NA	NA	Various CPs, cutaneous exposure	Various	For liquid splashes (chemicals, biological or radioactive): undress patient + copious water (± soap). For solids: scrape with wooden spatula.	4	B	Good decontaminant characteristics: effective, available, fast-acting, non-facilitating of skin penetration, easily removable without residue, safe for skin, affordable.
Chau (2012)[41]	Systematic review	NA	4 studies	Various CPs, ocular exposure	Various methods	Immediate irrigation with tap water achieves best results..	2++	B	Saline, Ringer's lactate, BSS Plus, or diphoterine also provide good results
Chilcott (2019)[42]	Prospective cohort	Healthy volunteers or with disability	86 volunteers	Methyl salicylate (simulated CW), cutaneous exposure	Clothing removal + DD vs. wet decontamination vs. technical decontamination	Most effective combination: DD + ladder-pipe wet shower + technical decontamination. Simple DD alone was next best.	2++	A	Clothing removal and DD are priority measures, ideally followed by wet and/or technical decontamination.

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moved clothing must be bagged in plastic, labeled, sealed, and disposed of as chemical waste. Personal items (watch, rings, earrings, necklaces) should also be removed and bagged with the patient's name. For ocular contamination, contact lenses, if present, should be removed.

A third area of consensus concerns timing: decontaminate as soon as possible, that is, immediately with whatever is at hand, and ideally within the first 2–3 minutes. This is especially critical for ocular exposures, in which prompt action may avert irreversible corneal injury. With strongly acidic, basic, or highly oxidizing CPs, the risk of early, severe cutaneous or ocular injury is high and the prevention window short, underscoring the importance of immediate decontamination.[15,16] Less certain is the latest time after exposure at which decontamination remains useful; this depends on how long the CP can persist on skin or eyes, prolonging toxicity. On skin, pesticides and hydrocarbons can persist for many hours; effective decontamination may still be possible up to 12 hours post exposure, whereas for other agents the window is < 6 hours.[17] For ocular contamination, decontamination may be reasonable up to 6 hours.[18]

Table 2. Characteristics of the studies included in the review (continued)

Author (year)	Study type	Target population	N/IS	CP / Exposure route	Decontaminant evaluated	Results	LE	GR	Comments
Delice (2023)[43]	Case report	Occupational accident	1 patient	Asphalt, cutaneous exposure	Sunflower oil	Apparent efficacy as a decontaminant.	3	E	Effective, safe, accessible, and economical method.
Dinesen (2023)[44]	Systematic review	9 studies	Various origins	Various CPs, cutaneous and ocular exposure	Diphoterine	One study found no difference in burn depth (diphoterine vs. control). Three studies reported greater pain reduction with diphoterine vs. control.	2++	B	No difference between diphoterine and water in burn depth.
Donoghue (2010)[45]	Case series	Occupational accidents	180 patients	Alkaline chemicals, cutaneous exposure	Diphoterine	Initial application of diphoterine associated with significantly better outcomes vs. water.	3	D	None.
Dorandeu (2023)[46]	Non-systematic review	NA	NA	CW (nerve agents, OPs), cutaneous exposure	Wet decontamination (water) vs. dry absorbent materials; possibility of RSDL for CW-OPs	Priority: wet decontamination (water). Dry methods possible but less effective. RSDL an option for CW-OPs.	4	B	Always undress patient and decontaminate early. Wet decontamination for corrosives. Hospital decontamination with water and soap.
Hall (2009)[47]	Non-systematic review	NA	NA	Various CPs, cutaneous and ocular exposure	Diphoterine	No adverse effects reported with diphoterine.	4	E	Conflicts of interest.
Hall (2006)[48]	Non-systematic review	NA	NA	Various CPs, cutaneous and ocular exposure	Water	Water reduces severity of chemical burns. Neutralizing (chelating, polyvalent, amphoteric, hypertonic) solutions should be evaluated.	4	E	Conflicts of interest.
Hall (2018)[49]	Non-systematic review	NA	NA	Various CPs, cutaneous exposure	Diphoterine vs. water	Several studies report greater pain and sequelae reduction with diphoterine.	4	E	Conflicts of interest.
Hall (2002)[50]	Non-systematic review	NA	NA	Various CPs, cutaneous and ocular exposure	Diphoterine	More effective than water for decontamination.	4	E	Conflicts of interest.
Houston (2005)[51]	Non-systematic review	NA	NA	CWs, cutaneous and ocular exposure	Several	Various (solids: soft brush/towel; skin: warm water + soap 5–6 min; eyes: water or saline for 20 min)	4	B	Most effective: undress patient (cut, don't pull clothes), remove contact lenses, use PPE.
Huang (2020)[52]	Case series	Poison Control Center consultations (Taiwan)	29 patients	TMAH, cutaneous exposure	Diphoterine	Workplace application reduces local and systemic toxicity.	3	E	Conflicts of interest.
Karimkhani (2014)[53]	Non-systematic review	NA	NA	Petroleum derivatives, cutaneous exposure	Water + soap vs. lipophilic solvents (dioctyl sulfosuccinate, etc.)	Lipophilic solvents derived from petroleum, such as dioctyl sulfosuccinate, are the best decontaminants	4	E	Such solvents are not available in clinical practice.
Kashetsky (2022)[54]	Systematic review	NA	10 documents	Various CPs, cutaneous exposure	Water	All studies using water, water + soap, or isopropanol showed incomplete efficacy.	2++	B	BWater best for hydrosoluble CPs; water + soap required for liposoluble CPs.
Keir (2023)[55]	Prospective cohort	Healthy volunteers	88 volunteers	PAHs, cutaneous exposure	Wipes, detergent, water	Significant reduction of PAHs on skin after water + soap vs. controls.	2+	B	No reduction of urinary PAH metabolites between decontaminated and controls.

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CWs used for warfare or terrorism are perceived as a low or nonexistent risk in Spain; however, the unstable political, military, and social contexts in countries that possess them necessitate preparedness.[19] For cutaneous CW contamination, after the initial steps already noted, the best immediate option is dry decontamination, using rolled absorbent paper, toilet paper, paper towels, wound dressings, pads, or similar materials to absorb CP from the skin.[20] If large-scale CW response systems are activated, this can be followed by wet decontamination using a ladder-pipe system (as described in Results) and then technical decontamination with water and soap. This sequence is complex, time consuming to set up, and requires firefighters and emergency medical services with clinicians and trained support staff; hence the importance of starting with disrobing and dry decontamination while other measures are prepared. In military settings, topical inactivation via hydrolysis and oxidation–chlorination with 0.5% sodium hypochlorite (diluted bleach) has been emphasized; however, this requires prolonged contact time, risks skin integrity, and is contraindicated for eyes and mucosae. Reactive skin decontamination lotion (RSDL) is a promising alternative

Table 2. Characteristics of the studies included in the review (continued)

Author (year)	Study type	Target population	N/IS	CP / Exposure route	Decontaminant evaluated	Results	LE	GR	Comments
Larner (2020)[56]	Prospective cohort	Healthy volunteers	48 volunteers	Methyl salicylate (simulated CW), cutaneous exposure	DD (wound dressing) vs. water shower (15 sec) vs. technical decontamination (baby oil wipe + 90 sec shower)	DD was the most effective; efficacy enhanced by water shower and technical decontamination.	2+	B	Methyl salicylate has properties similar to mustard gas.
Leary (2014)[57]	Non-systematic review	NA	NA	Various CPs and CWs, cutaneous exposure	Various decontaminants	Early decontamination can reduce morbidity and mortality caused by CWs.	4	B	Water alone can reduce morbidity/mortality of corrosives if applied within 3 min.
Lewis (2017)[58]	Case report	Occupational accident	1 patient	Sulfuric acid, cutaneous and ocular exposure	Diphoterine	Apparent benefit of diphoterine, but no comparative study with other options.	3	C	No sequelae observed.
Lewis (2020)[59]	Non-systematic review	NA	NA	Acidic CPs, cutaneous and ocular exposure	Various methods, incl. diphoterine and hexafluorine	Decontamination with diphoterine and hexafluorine should have a broader role in prehospital settings.	4	C	Lack of availability compensated by more standard measures such as water or, better, saline.
Lin (2010)[60]	Case series	Taiwan Poison Control Center	13 patients	TMAH, cutaneous exposure	Copious water irrigation	Appears best procedure to prevent systemic toxicity.	3	E	Study type does not allow conclusions on water's impact.
Lynn (2017)[61]	Systematic review	NA	6 studies	Various CPs, cutaneous and ocular exposure	Diphoterine	Safe and more effective than water for improving healing time, preventing sequelae, and controlling pain.	2++	B	Clinical studies methodologically weak, small populations, heterogeneous outcome measures.
Mathieu (2001)[62]	Case series	Occupational accident	11 patients	Hydrofluoric acid	Hexafluorine	Prevents burns and relieves pain immediately if applied early.	3	E	Conflicts of interest.
Merle (2005)[63]	Prospective cohort	Assaults, occupational & domestic accidents	66 patients	Alkaline CPs, ocular exposure	Saline vs. diphoterine	Time to corneal re-epithelialization shorter with diphoterine for grade 1–2 burns.	2-	B	Insufficient grade 3–4 cases to conclude.
Nahaboo-Solim (2021)[64]	Case series	Occupational or domestic ocular accidents	7 patients	Various CPs (alkalines), ocular exposure	Diphoterine vs. water	Faster pH normalization with diphoterine vs. water or saline.	3	E	Well tolerated; requires much less volume than other agents.
Nandamuri (2022)[65]	Systematic review	NA	7 documents	CPs and CWs, cutaneous exposure	DD	DD effective and first-choice while awaiting water + soap, which is most efficient.	2++	B	Method matters (blotting vs. rubbing, volume, prior instructions).
Nehles (2006)[66]	Case series	Occupational accidents	24 patients	Various CPs, cutaneous and ocular exposure	Diphoterine	After diphoterine decontamination, no burns or sequelae occurred.	3	E	Conflicts of interest.
Nogué (2012)[67]	Case series	Domestic and occupational accidents	36 patients	Various CPs, cutaneous and ocular exposure	Water vs. diphoterine	No adverse reactions with diphoterine.	3	C	Study design does not allow concluding diphoterine is superior to water.
Pita (2007)[68]	Non-systematic review	NA	NA	CWs	Various	Initially use absorbents like Fuller's earth. For gases: shower with water or water + soap. For liquids: water shower.	4	B	Prehospital decontamination crucial in CW incidents. Bleach 0.5% may be useful against vesicants and neurotoxins.

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for CWs. For ocular CW exposures: remove contact lenses and irrigate with water or saline for 20 minutes; eye patching is not recommended before ophthalmologic evaluation.

For patients arriving directly to hospital EDs, an on-site chemical decontamination area, such as one operating for years at a hospital in Barcelona, with specific protocols and appropriate decontamination and self-protection resources, is ideal.[21]

Regarding particular CP groups, solids on the skin are best removed by gentle scraping with a wooden spatula (tongue depressor–type), soft brush, or towel. Technique quality matters: when performing dry decontamination, pressing, rubbing, or press-and-rub influences efficacy, with combined press-and-rub performing best. After removing residues, wash with lukewarm water or water and soap; the oilier the CP, the more indicated the soap.

For liquids, the most ubiquitous, economical, and often effective decontaminant is tap water.[22] Application should be immediate, particularly for corrosives. Irrigation must be copious and maintained for ~20 minutes for both skin and eyes, and can be prolonged if local pH has not normalized. If a large surface area is involved, lukewarm water reduces hypothermia risk. Workplaces at risk for

Table 2. Characteristics of the studies included in the review (continued)

Author (year)	Study type	Target population	N/IS	CP / Exposure route	Decontaminant evaluated	Results	LE	GR	Comments
Saidinejad (2005)[69]	Case series	Pediatrics	2 patients	Propylene glycol and alkaline caustic, ocular exposure	Various	First choice is 0.9% saline. Alternatives: tap water, Ringer's lactate, balanced saline solution.	3	B	More neutral pH solutions may reduce ocular pain/irritation and improve tolerance to copious irrigation.
Schwartz (2012)[70]	Non-systematic review	NA	NA	CW (vesicants and OPs), cutaneous exposure	RSDL	RSDL superior to water, bleach, and dry absorbents for CW.	4	B	Not available in our setting. FDA approved. Military use.
Timperley (2019)[71]	Non-systematic review	NA	NA	CW (nerve agents, OPs), cutaneous exposure	Various	Gelling agents (silica, clay), phosphotriesterases, photocatalysts, others show decontaminant capacity.	4	C	Limited availability makes them clinically impractical; possible military use.
Viala (2005)[72]	Case series	5 patients, occupational accidents	5 patients	Tear gases, cutaneous and ocular exposure	Diphoterine	Improved symptoms.	3	E	Conflicts of interest.
Walsh (2022)[73]	Non-systematic review	NA	NA	Various CPs, cutaneous and ocular exposure	Various methods, incl. diphoterine	First DD, then abundant water for 20 min.	4	C	Diphoterine rapidly normalizes skin and conjunctival pH, but clinical studies are methodologically poor (high risk of bias).
Wiesner (2019)[74]	Prospective cohort	Occupational or domestic accidents	1,495 patients	Various CPs, ocular exposure	Diphoterine vs. water	Reduced morbidity with diphoterine.	2-	E	Conflicts of interest.
Yoshimura (2011)[75]	Case report	Occupational accident	1 patient	Hydrofluoric acid, cutaneous exposure	Hexafluorine	Apparent benefit.	3	E	Conflicts of interest.
Zack-Williams (2015)[76]	Case series	Occupational and domestic accidents	131 patients	Various CPs, cutaneous and ocular exposure	Diphoterine	Improved pH, reduced analgesia requirements.	3	C	No effect on healing time, hospital stay, or surgery need.

CW: Chemical Weapons; BSS: Balanced Saline Solution; DD: Dry Decontamination; GR: Grade of Recommendation; PAHs: Polycyclic Aromatic Hydrocarbons; N/IS: Number of Patients or Included Studies; LE: Level of Evidence; NA: Not Applicable; OPs: Organophosphates; CPs: chemical products; RL: Ringer's Lactate; RSDL: Reactive Skin Decontamination Lotion; TMAH: Tetramethylammonium Hydroxide.

chemical contamination must install showers and eyewash stations near workers to enable rapid action; Spain's National Institute for Occupational Safety and Health specifies requirements for these devices.[23] During cutaneous decontamination, especially with lipophilic CPs, soap should be used. Given its low cost, wide availability, and demonstrated effectiveness, water is the closest agent to a universal decontaminant.

Personal defense sprays and tear gases: Two case-series in this review describe cutaneous and especially ocular exposures; both suggest apparent benefit from diphoterine, though one discloses Conflicts of interest and the other lacks a comparator. A separate review not included here recommends, for ocular exposure, contact lens removal and irrigation with 0.9% NaCl for 10–15 minutes and, for skin, washing with water and soap, while noting limited evidence and high cost associated with diphoterine.[24]

Finally, three specific, and controversial, decontaminants are discussed: diphoterine, hexafluorine, and RSDL. Diphoterine is classified as a medical device (not a drug); its safety data sheet does not disclose active principles.[25] It is a colorless, odorless solution supplied for skin and eye irrigation after splashes of irritating or corrosive CPs and is demonstrably capable of rapidly buffering acids and bases. Independent studies reviewed report that diphoterine normalizes ocular surface pH faster than water after alkaline exposures; in mixed cutaneous/ocular series, it reduced analgesic needs; in a series of 180 cutaneous alkali exposures, initial diphoterine use outperformed water; in ocular alkali burns, it shortened corneal re-epithelialization time in grade 1–2 injuries versus normal saline; and in assaults with defense sprays, it was associated with greater symptom improvement than water. Across reports, no adverse effects were attributed to diphoterine. Overall, however, the evidence is weak: there are no randomized allocations, blinded assessors, or clear timing to decontamination—so diphoterine cannot be recommended as first-line decontamination at this time.[26]

Hexafluorine shows similar limitations; its technical sheet does not specify active principles beyond an aqueous solution with "amphoteric salts."[27] It is intended for washing ocular/cutaneous projections of hydrofluoric acid and fluorides in acidic media. This review found only two independent reviews citing favorable clinical cases; at present, evidence is insufficient to recommend routine availability as a decontaminant.[28]

RSDL is a mixture of Dekon 139 and 2,3-butanedione monoxime, using polyethylene glycol monomethyl ether and water as solvents.[29] The US Food and Drug Administration has authorized it as a medical device for skin decontamination after exposure to CWs and certain biologic toxins. It is supplied in sachets containing a sponge impregnated with RSDL to wipe contaminated skin.[30] A non-systematic review identifies RSDL as the best cutaneous decontaminant for vesicants and organophosphates; however, with extremely toxic CWs such as VX, application

Table 3. Main conclusions of this review

• COD (cutaneous and ocular decontamination) can help reduce morbidity, sequelae, and mortality after exposure to CPs.
• Decontamination personnel must use PPE to reduce the risk of becoming contaminated.
• No substance, material, or decontamination method can be considered a "universal decontaminant," since many factors influence its effectiveness. Therefore, COD must be adapted to the characteristics of the contaminant CP.
• Time is one of the most influential factors in the effectiveness of any decontamination. The shorter the delay, the more effective the measure. Ideally, decontamination should start immediately or within the first 3 minutes.
• In cutaneous contamination, the first measure is always to remove the patient's contaminated clothing, regardless of the type of CP.
• In cutaneous exposure to a CW especially nerve agents, the most effective decontamination is dry decontamination (using paper rolls, towels, gauze, pads, etc.).
• In the previous case (CW), the effectiveness of dry cleaning can be enhanced by subsequent showering with water or water and soap.
• Water-soluble CPs are best removed with water or water and soap, whereas lipid-soluble compounds always require water and soap.
• Although some metallic compounds (lithium, sodium, potassium, cesium, rubidium, and others) react violently with water and aqueous decontamination is theoretically contraindicated, after proper dry decontamination, the risk of washing with abundant water is lower than that of abstaining, and several authors recommend it.
• In ocular contamination, contact lenses should always be removed. Immediate washing is particularly important, and running water is the most available, economical, and probably the most effective option. Alternatives include 0.9% saline or Ringer's lactate solution.
• In workplaces at risk of chemical contamination, occupational safety and hygiene institutes have issued regulations on the required characteristics of showers and eyewash stations to rapidly decontaminate affected workers.
• Regarding diphoterine, some reviewed studies present conflicts of interest. Among independent studies, some show greater symptomatic improvement than water, but the level of evidence is low. The same applies to hexafluorine.
• RSDL lotion appears very effective for decontaminating cutaneous surfaces exposed to some chemical weapons (vesicants and organophosphates).

CW: chemical weapon; COT: cutaneous and ocular decontamination; PPE: personal protective equipment; CP: chemical product; RSDL: reactive skin decontamination lotion.

beyond 30 minutes post exposure does not prevent systemic effects.[31] Recent criminal events involving Novichok-A234 have renewed focus on effective decontamination, and RSDL has demonstrated efficacy,[32] though availability is currently limited to military or CBRN response teams.

This review has several limitations, including substantial variability in methods and populations, which hampers study comparability and generalization. Although the PICO (Population, Intervention, Comparison, Outcome) framework is widely used to structure therapy questions in systematic reviews, it was not deemed essential here because the objective was to assess the efficacy and safety of cutaneous and ocular decontamination methods across a very broad landscape of scenarios (workplace/domestic accidents, chemical terrorism), chemical agents (acids, bases, irritants, oxidants), exposed populations (general public, workers, public safety), and decontamination methods (dry, water, water-and-soap, diphoterine, hexafluorine, etc.). Rigid adherence to PICO could have narrowed the scope, as many available studies do not fit a direct intervention–outcome comparison. Instead, broad but clearly defined criteria were used to ensure comprehensive, rigorous evidence capture, following PRISMA to maximize transparency and reproducibility. Methodologic quality in many included studies was low to very low, weakening inference strength; conflicts of interest were also frequent in diphoterine and hexafluorine studies.

Clinical implications are shown in Table 3 and emphasize early COD as the key determinant to minimize injury and sequelae after CP exposure. Basic methods, dry decontamination and water or water-and-soap, are effective, but suitability depends on the contaminant's characteristics and clinical context. No single method or agent is universal, underscoring the need to tailor interventions to each case. Studies of specific decontaminants (diphoterine, hexafluorine) remain methodologically weak.

Future research should prioritize prospective, multicenter studies with uniform clinical outcomes and explicit assessment of time-to-decontamination. Protocols integrating chemical-agent characteristics, decontamination method, and patient factors would be valuable. Finally, expanding decontamination training across prehospital and hospital settings is essential.

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REFERENCES

1. Aranega R, Da Costa L, Salgado E. Limpieza doméstica con desenlace inesperado. Rev Esp Urg Emerg. 2023;2:59-60.
2. Hueso-Pinazo R, Arnao-Recuenco B, Payá-García AB, Martín-Ivorra R, Elorza-Montesinos P, Goitia-Leizaola A, et al. Características clínicas y gestión asistencial de las intoxicaciones agudas atendidas en el servicio de urgencias de un hospital universitario. Rev Esp Urg Emerg. 2025;4:21-9.
3. González-Díaz A, Matos-Castro S, Arruabarrena Urrestarazu N, González Valladares E, Molina Padilla S, Ferrer Dufol A, et al. Evolución de las intoxicaciones agudas por productos químicos en el quinquenio 2015-2019, regis-

tradas por el Sistema Español de Toxicovigilancia (SETv). Rev Esp Urg Emerg. 2023;2:30-5.
4. Palao R, Monge I, Ruiz M, Barret JP. Chemical burns: pathophysiology and treatment. Burns. 2010;36:295-304.
5. Cheong H, Kim J. Fatal hydrofluoric acid poisoning: histologic findings and review of the literature. Forensic Sci Med Pathol. 2023;19:67-71.
6. Hunter DM, Timerding BL, Leonard RB, McCalmont TH, Schwartz E. Effects of isopropyl alcohol, ethanol, and polyethylene glycol/industrial methylated spirits in the treatment of acute phenol burns. Ann Emerg Med. 1992;21:1303-7.
7. Brent J. Dermal decontamination for corrosive exposures. Clin Toxicol. 2014;52:153.
8. Danoy A, Durmaz K, Paoletti M, Vachez L, Roul A, Sohier J, et al. Aqueous suspensions of Fuller's earth potentiate the adsorption capacities of paraoxon and improve skin decontamination properties. J Hazard Mater. 2022;425:127714.
9. Harbour R, Miller J. A new system for grading recommendations in evidence based guidelines. BMJ. 2001;323:334-6.
10. Harris RP, Helfand M, Woolf SH, Lohr KN, Mulrow CD, Teutsch SM, et al. Current methods of the US Preventive Services Task Force: a review of the process. Am J Prev Med. 2001;20:21-35.
11. U.S. Department of Health and Human Services. Prism: Primary response incident scene management. (Consultado 6 Noviembre 2024). Disponible en: https://www.medicalcountermeasures.gov/barda/cbrn/prism/
12. Stewart CE. Chemical skin burns. Am Fam Physician. 1985;31:149-57.
13. Bizrah M, Yusuf A, Ahmad S. An update on chemical eye burns. Eye (Lond). 2019;33:1362-77.
14. Rasoloharimahefa-Rasamoela M, Bouland C. Évaluation du risque par les professionnels de la santé et les équipes de secours lors d'incidents chimiques. Sante Publique. 2024;36:109-19.
15. Greenwood JE, Tan JL, Ming JC, Abell AD. Alkalis and Skin. J Burn Care Res. 2016;37:135-41.
16. Korkmaz I, Palamar M, Egrilmez S, Yagci A, Barut Selver O. Ten years of pediatric ocular chemical burn Experience in a tertiary eye care center in Turkey. Eye Contact Lens. 2022;48:175-9.
17. Canut E, Calderón S. Medidas de descontaminación cutánea. En: Nogué S, Salgado E, Martínez L. Toxicología clínica. Bases para el diagnóstico y el tratamiento de las intoxicaciones en servicios de urgencias, áreas de vigilancia intensiva y unidades de toxiciología. Barcelona: Elsevier; 2024. pp. 238-40.
18. Torras J, Amigó M. Medidas de descontaminación ocular. En: Nogué S, Salgado E, Martínez L. Toxicología clínica. Bases para el diagnóstico y el tratamiento de las intoxicaciones en servicios de urgencias, áreas de vigilancia intensiva y unidades de toxiciología. Barcelona: Elsevier; 2024. pp. 241-3.
19. Pita R, Ishimatsu S, Robles R. Actuación sanitaria en atentados terroristas con agentes químicos de guerra: más de diez años después de los atentados con sarín en Japón, (parte 1). Emergencias. 2007;19:323-36.
20. Thors L, Wigenstam E, Qvarnström J, Wästerby P, Öberg L, Bucht A. Immediate dry decontamination using efficient absorbent materials is beneficial following skin exposure to low-volatile toxic chemicals. J Appl Toxicol. 2024;44:1361-71.
21. Amigó M, Uría E, Canut E, Sánchez JA, Fernández F, Nogué S. Exposición a productos químicos. Descontaminación cutánea y ocular. Rev ROL Enferm. 2018;41:102-10.
22. Whalen MJ, Aizenberg AM, Shirazi FM, Berrigan JJ, Walter FG. Skin decontamination with and without water irrigation. Disaster Med Public Health Prep. 2024;18:e220.
23. Mendoza M. Duchas y lavaojos: normativa de aplicación. (Consultado 30 Octubre 2024). Disponible en: https://www.farmaindustrial.com/require/archivos/articulos/descarga/bdOTNxrE2yTYft2UPDHhAC1mU.pdf
24. Carron PN, Yersin B. Management of the effects of exposure to tear gas. BMJ. 2009;338:b2283.
25. Diphoterine. Hoja de datos de seguridad. (Consultado 31 Octubre 2024). Disponible en: https://www.prevor.com/app/uploads/sites/3/2020/08/grv-aas-fds-diphoterine-gbr-actu9.pdf
26. Lucyk S. Decontamination principles. Prevention of dermal, ophthalmic, and inhalational absorption. En: Nelson LS, Howland MA, Lewin NA, Smith SW, Goldfrank LR, Hoffman RS. Goldfrank's. Toxicological emergencies. New York: Mc Graw Hill Education; 2019. pp. 71-5.
27. Hexafluorine. Ficha de datos de seguridad. (Consultado 31 Octubre 2024). Disponible en: https://www.prevor.com/app/uploads/sites/5/2021/01/grv-qal-fds-hexafluorine-es-actu-9.pdf
28. Su MK. Hydrofluoric acid and fluorides. En: Nelson LS, Howland MA, Lewin NA, Smith SW, Goldfrank LR, Hoffman RS. Goldfrank's. Toxicological emergencies. New York: Mc Graw Hill Education; 2019. pp. 1397-402.
29. Loción RSDL. Ficha de datos de seguridad. (Consultado 4 Noviembre 2024). Disponible en: https://trueprepper.com/wp-content/uploads/2018/06/RSDL-MSDS-2006.pdf
30. Loción RSDL. Guía práctica de utilización. (Consultado 4 Noviembre 2024). Disponible en: https://trueprepper.com/rsdl-reactive-skin-decontamination-lotion/
31. Joosen MJ, van der Schans MJ, Kuijpers WC, van Helden HP, Noort D. Timing of decontamination and treatment in case of percutaneous VX poisoning: a mini review. Chem Biol Interact. 2013;203:149-53.
32. Cornelissen AS, van den Berg RM, Langenberg JP, van Grol M, Bross R, Pittman J, et al. Effective skin decontamination with RSDL® (reactive skin decontamination lotion kit) following dermal exposure to a Novichok class nerve agent. Chem Biol Interact. 2024;395:111001.
33. Alexander KS, Wasiak J, Cleland H. Chemical burns: Diphoterine untangled. Burns. 2018;44:752-66.
34. Amigó M, Fernández F, Velasco V, Nogué S. Agresiones realizadas con espráis de defensa personal atendidas en el área de descontaminación química de urgencias. A propósito de 15 casos. Emergencias. 2016;28:349-52.
35. Amigó M, Uría E, Canut E, Calderón S, Nogué S. Evaluación epidemiológica, clínica, terapéutica y evolutiva de las descontaminaciones químicas realizadas en urgencias. Rev Esp Urg Emerg. 2024;3:214-20.
36. Amlôt R, Carter H, Riddle L, Larner J, Chilcott RP. Volunteer trials of a novel improvised dry decontamination protocol for use during mass casualty incidents as part of the UK'S Initial Operational Response (IOR). PLoS One. 2017;12:e0179309.
37. Atley K, Ridyard E. Treatment of hydrofluoric acid exposure to the eye. Int J Ophthalmol. 2015;8:157-61.
38. Brent J. Water-based solutions are the best decontaminating fluids for dermal corrosive exposures: a mini review. Clin Toxicol (Phila). 2013;51:731-6.
39. Chai H, Chaudhari N, Kornhaber R, Cuttle L, Fear M, Wood F, et al. Chemical burn to the skin: A systematic review of first aid impacts on clinical outcomes. Burns. 2022;48:1527-43.
40. Chan HP, Zhai H, Hui X, Maibach HI. Skin decontamination: principles and perspectives. Toxicol Ind Health. 2013;29:955-68.
41. Chau JP, Lee DT, Lo SH. A systematic review of methods of eye irrigation for adults and children with ocular chemical burns. Worldviews Evid Based Nurs. 2012;9:129-38.
42. Chilcott RP, Larner J, Durrant A, Hughes P, Mahalingam D, Rivers S, et al. Evaluation of US Federal Guidelines (Primary Response Incident Scene Management [PRISM]) for mass decontamination of casualties during the initial operational response to a chemical incident. Ann Emerg Med. 2019;73:671-84.
43. Delice O, Doru HI. A rare chemical, biological, and nuclear hazard event: Asphalt burns. JCPSP. 2023;33:58-9.
44. Dinesen F, Pape P, Vestergaard MR, Rasmussen LS. Diphoterine for chemical burns of the skin: A systematic review. Eur Burn J. 2023;4:55-68.
45. Donoghue AM. Diphoterine for alkali chemical splashes to the skin at alumina refineries. Int J Dermatol. 2010;49:894-900.
46. Dorandeu F, Singer C, Chatfield S, Chilcott RP, Hall J. Exposure to organophosphorus compounds: best practice in managing timely, effective emergency responses. Eur J Emerg Med. 2023;30:402-7.
47. Hall AH, Cavallini M, Mathieu L, Maibach HI. Safety of dermal diphoterine application: an active decontamination solution for chemical splash injuries. Cutan Ocul Toxicol. 2009;28:149-56.
48. Hall AH, Maibach HI. Water decontamination of chemical skin/eye splashes: a critical review. Cutan Ocul Toxicol. 2006;25:67-83.
49. Hall AH, Mathieu L, Maibach HI. Acute chemical skin injuries in the United States: a review. Crit Rev Toxicol. 2018;48:540-4.
50. Hall AH, Blomet J, Mathieu L. Diphoterine for emergent eye/skin chemical splash decontamination: a review. Vet Hum Toxicol. 2002;44:228-31.
51. Houston M, Hendrickson RG. Decontamination. Crit Care Clin. 2005;21:653-72.
52. Huang CK, Hall AH, Wu ML, Yang CC, Hung DZ, Mao YC, et al. Presentations of tetramethylammonium hydroxide dermal exposure and the valuable potential of diphoterine solution in decontamination: a retrospective observational study. BMC Pharmacol Toxicol. 2020;2:83.
53. Karimkhani C, Amir M, Dellavalle RP, Ipaktchi K. Current concepts for oil decontamination of crush injuries: a review. Patient Saf Surg. 2014;8:22.
54. Kashetsky N, Law RM, Maibach HI. Efficacy of water skin decontamination in vivo in humans: A systematic review. J Appl Toxicol. 2022;42:346-59.
55. Keir JLA, Kirkham TL, Aranda-Rodriguez R, White PA, Blais JM. Effectiveness of dermal cleaning interventions for reducing firefighters' exposures to PAHs and genotoxins. J Occup Environ Hyg. 2023;20:84-94.
56. Larner J, Durrant A, Hughes P, Mahalingam D, Rivers S, Matar H, et al. Efficacy of different hair and skin decontamination strategies with identification of associated hazards to first responders. Prehosp Emerg Care. 2020;24:355-68.
57. Leary AD, Schwartz MD, Kirk MA, Ignacio JS, Wencil EB, Cibulsky SM. Evidence-based patient decontamination: an integral component of mass exposure chemical incident planning and response. Disaster Med Public Health Prep. 2014;8:260-6.
58. Lewis CJ, Al-Mousawi A, Jha A, Allison KP. Is it time for a change in the approach to chemical burns? The role of Diphoterine® in the management of cutaneous and ocular chemical injuries. J Plast Reconstr Aesthet Surg. 2017;70:563-7.
59. Lewis CJ, Hodgkinson EL, Allison KP. Corrosi-

ve attacks in the UK - Psychosocial perspectives and decontamination strategies. Burns. 2020;46:213-8.
60. Lin CC, Yang CC, Ger J, Deng JF, Hung DZ. Tetramethylammonium hydroxide poisoning. Clin Toxicol (Phila). 2010;48:213-7.
61. Lynn DD, Zukin LM, Dellavalle R. The safety and efficacy of Diphoterine for ocular and cutaneous burns in humans. Cutan Ocul Toxicol. 2017;36:185-92.
62. Mathieu L, Nehles J, Blomet J, Hall AH. Efficacy of hexafluorine for emergent decontamination of hydrofluoric acid eye and skin splashes. Vet Hum Toxicol. 2001;43:263-5.
63. Merle H, Donnio A, Ayeboua L, Michel F, Thomas F, Ketterle J, et al. Alkali ocular burns in Martinique (French West Indies) Evaluation of the use of an amphoteric solution as the rinsing product. Burns. 2005;31:205-11.
64. Nahaboo-Solim MA, Lupion-Duran TM, Rana-Rahman R, Patel T, Ah-Kine D, Ting DSJ. Clinical outcomes and safety of Diphoterine® irrigation for chemical eye injury: A single-centre experience in the United Kingdom. Ther Adv Ophthalmol. 2021;13:25158414211030429.
65. Nandamuri S, Feschuk AM, Maibach HI. A review of the efficacy of easily accessible dry decontaminants for human chemical contamination. J Appl Toxicol. 2022;42:950-60.
66. Nehles J, Hall AH, Blomet J, Mathieu L. Diphoterine for emergent decontamination of skin/eye chemical splashes: 24 cases. Cutan Ocul Toxicol. 2006;25:249-58.
67. Nogué S, Amigó M, Uría E, Fernández F, Velasco V. Actividad de un área de descontaminación química de un servicio de urgencias. Emergencias. 2012;24:203-7.
68. Pita R, Ishimatsu S, Robles R. Actuación sanitaria en atentados terroristas con agentes químicos de guerra: más de diez años después de los atentados con sarín en Japón (parte 2). Emergencias. 2007;19:337-46.
69. Saidinejad M, Burns MM. Ocular irrigant alternatives in pediatric emergency medicine. Pediatr Emerg Care. 2005;21:23-6.
70. Schwartz MD, Hurst CG, Kirk MA, Reedy SJ, Braue EH Jr. Reactive skin decontamination lotion (RSDL) for the decontamination of chemical warfare agent (CWA) dermal exposure. Curr Pharm Biotechnol. 2012;13:1971-9.
71. Timperley CM, Abdollahi M, Al-Amri AS, Baulig A, Benachour D, Borrett V, et al. Advice on assistance and protection from the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons: Part 2. On preventing and treating health effects from acute, prolonged, and repeated nerve agent exposure, and the identification of medical countermeasures able to reduce or eliminate the longer term health effects of nerve agents. Toxicology. 2019;413:13-23.
72. Viala B, Blomet J, Mathieu L, Hall AH. Prevention of CS "tear gas" eye and skin effects and active decontamination with Diphoterine: preliminary studies in 5 French Gendarmes. J Emerg Med. 2005;2:5-8.
73. Walsh K, Hughes I, Dheansa B. Management of chemical burns. Br J Hosp Med (Lond). 2022;83:1-12.
74. Wiesner N, Dutescu RM, Uthoff D, Kottek A, Reim M, Schrage N. First aid therapy for corrosive chemical eye burns: results of a 30-year longitudinal study with two different decontamination concepts. Graefes Arch Clin Exp Ophthalmol. 2019;257:1795-803.
75. Yoshimura CA, Mathieu L, Hall AH, Monteiro MG, de Almeida DM. Seventy per cent hydrofluoric acid burns: delayed decontamination with hexafluorine® and treatment with calcium gluconate. J Burn Care Res. 2011;32:e149-54.
76. Zack-Williams SD, Ahmad Z, Moiemen NS. The clinical efficacy of Diphoterine in the management of cutaneous chemical burns: a 2-year evaluation study. Ann Burns Fire Disasters. 2015;28:9-12.