GUIDELINES FOR MANAGEMENT OF CHEMICAL BURNS IN THE WORKPLACE

Chemical Risk Functional Group

Asociación Española de Especialistas en Medicina del Trabajo

May, 2.023

AUTHORS

Chemical Risk Functional Group in the Occupational Environment AEEMT

Editorial Team

Arias Peraza, Susana
Bermejo Bermejo, Marta
Cabrera Fernández, Enrique
Calvo Cerrada, Beatriz
González Domínguez, María Eugenia
Marín Hidalgo, María Francisca
Rueda Garrido, Juan Carlos

Imagen de Portada.
Emil Nolde
Nubes rojas (detalle)
Acuarela sobre papel hecho a mano. 34,5 x 44,7 cm

INDEX

ABBREVIATIONS

ABC: Airway, Breathing, and Circulation
AI: Artificial Intelligence
ECG: Electrocardiogram
EPA: Environmental Protection Agency
PPE: Personal Protective Equipment
HR: Heart Rate
HF: Hydrofluoric acid
RR: Respiratory Rate
INE: National Institute of Statistics
WHO: World Health Organization
OSHA: Occupational Safety and Health Administration
REACH: Registration, Evaluation, Authorization, and Restriction of Chemicals
SatO2: Oxygen Saturation
SS: Saline solution
BP: Blood Pressure

INTRODUCTION

This practical guide arises from the need to establish homogeneous and unified criteria regarding the approach to injuries caused by chemical contact. It has been developed through the work of the members of the Chemical Risk functional group of the Spanish Association of Occupational Medicine Specialists, and as a novelty, it has benefited from the collaboration of Artificial Intelligence (AI) using OpenAI's GPT-4.

Chemical burns can be defined as injuries to the skin and tissues caused by exposure to chemical substances such as acids, alkalis, and other chemicals. Chemical burns can occur at home, in the workplace, or anywhere chemicals are handled.

Chemical burns in the workplace represent a significant risk to the health and safety of employees, especially in industries where hazardous chemicals are handled, such as the chemical industry, construction, and scientific research (Hettiaratchy & Dziewulski, 2004). These burns can cause severe damage to the skin, eyes, and other tissues, resulting in pain, scarring, disability, and, in extreme cases, death (Gülbitti, Cole & Hewitt, 2017).

According to the World Health Organization (WHO), it is estimated that around 265,000 burn-related deaths occur worldwide each year, with approximately 10% of these burns caused by chemical substances.

In the United States, the Environmental Protection Agency (EPA) reports approximately 60,000 chemical burn injuries annually. Additionally, the Occupational Safety and Health Administration (OSHA) reports that chemical burns are one of the most common injuries in the workplace, with workers in the chemical industry, construction, and agriculture at a higher risk of suffering chemical burns.

Chemical burns are a significant cause of workplace injuries, but they also frequently occur in domestic settings. According to the National Institute of Statistics (INE) in Spain, a total of 1,064 work-related accidents due to exposure to chemical substances were recorded in 2019, of which 22 were fatal. Furthermore, according to the Ministry of Health, there were a total of 1,200 hospitalizations due to chemical burns in Spain in 2018.

In Spain, there are specific regulations and standards to prevent and control risks associated with exposure to chemical substances in the workplace. For example, the Law on Occupational Risk Prevention establishes employers' obligation to assess occupational risks and adopt appropriate preventive measures. Additionally, the European REACH Regulation (Registration, Evaluation, Authorization, and Restriction of Chemicals) establishes a system for registering and evaluating chemical substances to ensure their safety. There are applications available to assist in the assessment and management of risks related to dermal exposure to hazardous chemicals in the workplace, in accordance with the Royal Decree 374/2001, of April 6, on the protection of workers' health and safety against risks related to chemical agents in the workplace, such as RISKOFDERM (INSST, 2012) and ECETOC-TRA (ECETOC, n.d.).

In summary, chemical burns are a significant problem in Spain, especially in the workplace. It is important to take appropriate preventive measures and have decontamination protocols in the event of a chemical burn to minimize damage and prevent complications.

According to the American Burn Association, an estimated 40,000 hospitalizations due to burns occur annually in the United States, of which approximately 5% are chemical burns. Chemical burns are more common in males than females and mainly affect the hands and eyes.

Focusing on Spain, burns represent a significant public health issue, and chemical burns are one of the most frequent causes of occupational injuries in the country. According to a study conducted in the Valencia Community between 1990 and 2004, 2,326 cases of burns were recorded, of which 9.3% were chemical burns (Pérez et al., 2008). Another study carried out by the Plastic Surgery and Burns Department at La Paz University Hospital in Madrid found that chemical burns accounted for 4.6% of all treated burns in the hospital between 2000 and 2005. In other studies, such as the one conducted at La Paz University Hospital in Madrid between 2005 and 2015, it was shown that 13.8% of admitted burn patients had chemical burns (López Gutiérrez et al., 2017).

A more recent study published in the Burns journal in 2017 evaluated patterns of chemical burns in the Burn Unit of Virgen del Rocío University Hospital in Seville between 2002 and 2014. The results showed that 4.4% of the burns treated in the unit were chemical burns, with alkalis and acids being the most commonly involved substances. The study also indicated that the hands and arms were the most affected areas in chemical burns.

In the exclusive context of the workplace, as mentioned, chemical burns are a common problem, especially among workers who handle chemicals and their derivatives. A study conducted in chemical companies in Catalonia showed that 9.1% of workers had suffered chemical burns in the previous year (Rodríguez et al., 2010).

Regarding the affected areas of the body, in general, chemical burns tend to primarily affect the hands and eyes, and the severity of the injury depends on the quantity and concentration of the chemical substance, the duration of exposure, penetration, mechanism of action, and the affected body surface.

The origin of contact with chemical products can vary significantly, with one of the most frequent being the handling of chemicals in the work environment, such as in the chemical industry, agriculture, and cleaning. However, we must also consider non-work-related origins in situations involving household cleaning tasks or DIY projects. The common factor in most of these accidents is the use of chemical products without knowledge of their potential harm. We cannot ignore cases resulting from assaults, whether through domestic violence or other types of attacks with the intention of causing harm through chemical burns. Additionally, accidental etiology through ingestion and attempted self-harm represents a significant portion of hospital admissions to intensive care units.

In the scope covered by this guide, the effects resulting from occupational exposure to chemical contaminants can be local, caused by splashes, leading to acute skin disorders such as irritations or burns, or prolonged contact effects such as dermatitis or sensitizations.

We can also observe other systemic effects, causing alterations or damage to specific organs or systems (liver, kidney, etc.) once absorbed and distributed throughout the body. Skin absorption of substances can contribute significantly to the overall dose absorbed in occupational exposure. In many situations, dermal exposure is the main contributing source to this dose, as is the case with chlorophenols, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and particularly pesticides.

When chemical substances come into contact with the skin, they must traverse several layers until reaching the capillaries to be absorbed systemically. In summary, the skin is a variable thickness covering that envelops the body and serves functions of insulation, protection, and exchange. It consists of the epidermis (outermost stratum corneum layer), dermis (composed primarily of collagen), and the hypodermis (the deepest layer composed of adipose tissue).

The epidermis constitutes the first barrier of protection against external aggressions, including chemical agents. The severity of substance penetration depends on factors such as product nature, chemical composition, temperature at the time of contact, duration of exposure, and the previous condition of the skin in the area of contact.

To focus the objective of this guide, our attention will be directed towards those chemical products capable of causing burns upon contact with the skin and mucous membranes, as well as those that cause acute injuries to the respiratory tract. This group of chemicals includes corrosive and irritant substances that pose a significant danger and can cause severe chemical burns upon contact with the skin or ocular tissue.

PATHOPHYSIOLOGY OF CHEMICAL CONTACT

We must distinguish between thermal burns, which involve the transfer of heat through radiation and conduction in a primarily physical plane, and chemical aggression that triggers true molecular reactions. The process of chemical burn production, fundamentally a chemical reaction, can be summarized in terms of phases based on the penetration of the chemical into the cutaneous layers (Maibach & Hall, 2014):

1. The first phase occurs with the contact of the chemical substance with the skin or ocular mucosa, representing the initial superficial exposure, where the tissue offers resistance to penetration.
2. The second phase refers to cutaneous and/or ocular penetration, during which the chemical diffuses through the inner layers of the tissue, resulting in a reversible type of injury.
3. The third phase is characterized by the occurrence of a chemical reaction with the biochemical components, leading to an inflammatory response and cellular destruction.

These different phases can occur within minutes or even seconds, depending on various evolving factors such as exposure time, chemical product and concentration, as well as the temperature of the product. Therefore, it is crucial to react promptly to rapidly halt the process from the initial moments.

Etiology

When analyzing chemical contact according to frequency, special mention must be made of the cleaning products we use in our daily lives, both in domestic and occupational settings. Nowadays, detergents are mainly manufactured from a variety of petrochemical and/or oleochemical products (derived from fats and oils). A detergent (or surfactant) is a chemical compound with surface-active properties that enable it to dissolve dirt. Among the detergents that can be found among the list of potential chemicals, not only in domestic but also in occupational cleaning tasks, are:

• Laundry products: They have a formula that allows for the removal of dirt, whitening, fabric softening, and care.
• Dishwashing products: Among them, there are detergents for hands, dishes, and glassware, as well as other specific products.
• Cleaning products: These are used to clean painted, plastic, metallic, porcelain, and glass surfaces. Since no single product has optimal efficacy on all surfaces and stains, a wide variety of products has been developed to facilitate easy and effective cleaning by combining different properties.

Regarding the different ingredients that can be found in these products, attention should be paid to:

• Sodium hypochlorite for bleaching, brightening, and stain removal.
• Alkaline products (ammonium, sodium hydroxide, etc.). Alkalinity is useful for neutralizing acidity, grease, and oil stains. Therefore, detergents are more effective when they are basic.
• Acids (nitric acid, acetic acid, hydrochloric acid, etc.) for neutralizing or adjusting the alkalinity of other ingredients and because certain specific cleaning products require more acidity to dissolve mineral sediments.
• Coloring agents (pigments or dyes).
• Solvents: They are used to prevent separation or deterioration of ingredients in liquid products and to dissolve organic stains.

If we consider the type of chemical and its properties, we can differentiate burns caused by acids, bases or alkalis, organic solvents, and oxidizing agents:

1. Burns caused by acids:
Burns caused by acids result from exposure to corrosive acidic substances such as sulfuric acid, hydrochloric acid, or nitric acid. Typical properties of acids include low pH (less than 7), corrosiveness, and the ability to cause direct tissue damage, resulting in deep burns. Acids usually induce coagulation and necrosis of tissue proteins, leading to the formation of a dry crust that acts as a protective barrier.

2. Burns caused by alkalis:
Burns caused by alkalis occur when there is exposure to corrosive alkaline substances such as sodium hydroxide (caustic soda) or potassium hydroxide (caustic potash). Alkalis have a high pH (greater than 7) and can cause extensive damage to tissues due to their ability to dissolve lipids and proteins, resulting in deep burns as they can more easily penetrate tissues. Burns caused by these products can lead to tissue necrosis, edema, and hemorrhages.

3. Burns caused by organic solvents:
Organic solvents such as acetone, benzene, or toluene can cause chemical burns upon contact with the skin. These solvents can quickly penetrate the skin and damage underlying tissues, resulting in superficial or deep burns depending on the duration of exposure and the concentration of the solvent. Additionally, they can cause chemical burns through prolonged contact with the skin or inhalation of their vapors. These substances can dissolve the skin's natural oils, leading to irritation and burns. Furthermore, organic solvents can be toxic to the central nervous system and liver.

4. Burns caused by vesicant agents:
Vesicant agents such as mustard gas (sulfur mustard) or lewisite are chemical substances that can cause burns and blisters on the skin. These agents can cause severe irritation to the skin and eyes, and they can also affect the respiratory tract if inhaled.

5. Burns caused by caustic chemicals:
Caustic chemicals include substances such as chlorine, ammonia, or calcium hydroxide. These chemicals can cause chemical burns and tissue damage due to their high reactivity and corrosive properties.

6. Reducing agents:
Products such as sodium sulfite. These are chemical substances that have the ability to donate electrons to other substances, resulting in a chemical reduction reaction. They can be highly corrosive and cause significant damage to tissues.

7. Chelators:
Chelating agents like calcium or magnesium can be corrosive or irritating to human tissues in certain cases. This is due to their ability to form complexes with these ions and disrupt the ionic balance in cells and tissues.

8. Alkylating agents:
Examples include sulfur chloride (mustard gas). In general, alkylating agents can be corrosive or harmful to human tissues due to their highly reactive nature. Their ability to modify molecular structures and damage cellular DNA can have detrimental effects on tissues and organs.

It is important to note that the severity of chemical burns depends on the type of chemical substance involved, its concentration, the product's temperature, the duration of contact, and the amount of substance that comes into contact with the skin. Furthermore, the mechanism of chemical burn production can vary depending on the chemical substance involved and the way in which the contact occurs. For instance, chemical burns can be produced by direct contact with the substance, inhalation of its vapors, ingestion of the substance, among other forms.

Types of Chemical Reactions

The types of chemical reactions that can cause injury in the occupational setting can be summarized by the following mechanisms:

1. Protein denaturation: Chemical substances can denature proteins in the skin and underlying tissues, leading to cellular death and tissue degradation. This mechanism of injury is common in chemical burns caused by acids and bases.

2. Oxidation: Some chemical substances can oxidize tissues, resulting in cellular death and tissue degradation. This mechanism of injury is common in chemical burns caused by caustic substances.

3. Inflammation: Exposure to chemical substances can trigger an inflammatory response in the skin and underlying tissues, leading to cellular death and tissue degradation. This mechanism of injury is common in chemical burns caused by irritant substances.

4. Absorption: Certain chemical substances can be absorbed by the skin and underlying tissues, causing cellular death and tissue degradation. This mechanism of injury is common in chemical burns caused by caustic substances.

Severity Factors

When assessing the severity of a chemical burn, several factors should be considered that can worsen the injury to the worker and should be modified or minimized to improve the healing process of the burn. These factors generally include (Rastogi, 2008) (Mowad, 2016):

1. Chemical type: The nature of the chemical itself is an important factor. Some chemicals are more corrosive or toxic than others, which can affect the severity of the burn.

2. Chemical concentration: The concentration of the chemical also plays a significant role in the severity of the burn. Higher concentrations of chemicals can cause more severe burns.

3. Duration of contact: The length of time the chemical is in contact with the skin also influences the severity of the burn. The longer the chemical remains in contact with the skin, the greater the damage. This factor is crucial in the care of our workers.

4. Contact area: The amount of skin exposed to the chemical also affects the severity of the burn. Burns covering larger areas of the body can be more severe and challenging to treat. Certain body areas carry a higher risk of functional sequelae, such as the hands, face, genitals, and skin folds (Fig. 1).

5. Individual sensitivity: An individual's skin sensitivity to a specific chemical can also influence the severity of the burn. Some people may be more susceptible to chemical burns than others due to differences in skin composition, skin conditions, or allergies.

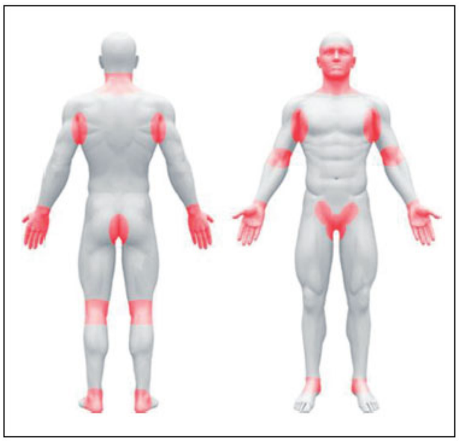
6. Depth of penetration: The depth to which the chemical penetrates the skin is also an important factor. Chemicals that penetrate deeper can cause more severe burns and damage to underlying tissues. This factor is inherent to the characteristics and properties of the chemical.

7. Chemical temperature: The temperature at which the chemical is present can affect the severity of the burn. Hot chemicals can cause additional thermal burns alongside chemical burns, increasing the severity of the damage to the skin. Moreover, certain chemicals may react differently at different temperatures, affecting how they interact with the skin and the damage they cause.

8. Pressure: The pressure of the chemical product projection can also affect the severity of the injury, as high-pressure projections facilitate the penetration of the chemical into the tissue.

It is important to consider the temperature of the chemical when developing a chemical decontamination protocol and when assessing the severity of a chemical burn. Additionally, cooling the affected area should be implemented to counteract the cumulative effects of high temperature and the inherent effects of the chemical.

Fig. 1. Functional segments with a higher probability of causing functional sequelae. (Salmerón-González E, 2017)



DIAGNOSIS

To establish the diagnosis of a situation in the workplace following a worker's contact with chemicals, the following points should be considered to ensure proper chemical decontamination after assessing the injuries and the worker's condition (Hettiaratchy & Papini, 2004) (Kales & Christiani, 2004):

1. Initial assessment: When receiving information about an incident involving chemical contact, it is crucial to conduct an initial assessment of the affected worker and their environment. This involves identifying the chemical involved, the route of exposure (e.g., inhalation, ingestion, dermal contact), and the duration of exposure. Gathering information not only from the affected individual but also from the worker's surroundings (colleagues, safety officer) is critical at this initial stage.

2. Burn extent: Carefully examine the affected area to determine the extent of the chemical burn. This may involve measuring the size of the lesion and evaluating the depth of the burn (superficial, partial, or full thickness). The worker should be undressed, and their clothing should be sealed in a bag for further analysis of the chemical contact.

3. Time elapsed since contact: Record the time that has passed since the chemical contact occurred until the assessment is performed. This can be useful in determining the severity of the injury and guiding appropriate treatment.

4. Skin condition: Inspect the skin in the affected area, looking for signs of redness, swelling, blisters, ulcers, or necrosis. This can provide valuable information about the severity of the injury and the need for medical intervention.

5. Color of the lesion: Observe the color of the lesion as it can indicate the depth of the burn and the type of chemical involved. For example, acid burns may appear whitish, while alkali burns may be grayish, as seen in contact with phenol, which has a characteristic burn color.

6. Odor and chemical residues: Evaluate whether there is a distinctive odor or chemical residues on the worker's skin or clothing. This can help identify the chemical involved and provide information about the need for additional decontamination. It provides additional data about the type of chemical involved.

7. Treatment and follow-up: Based on the diagnostic assessment, initiate appropriate treatment for the affected worker. This may include decontamination, administration of medication, wound care, and short- and long-term medical follow-up.

8. Prevention and education: After addressing the incident, it is crucial to review safety practices in the workplace and provide additional training to employees on how to prevent and handle future incidents of chemical contact. This learning should also be integrated into the accident investigation.

Based on the depth of the burn, different types of burns are traditionally and generally classified as follows:

a) First-degree burns: This type of burn affects only the top layer of the skin (epidermis). It is characterized by redness, pain, and sensitivity to touch. First-degree chemical burns are similar to sunburns and usually heal within a few days without leaving scars.

b) Second-degree burns: This type of burn affects both the top layer of the skin (epidermis) and the underlying layer of the skin (dermis). It is characterized by blisters, redness, intense pain, and sensitivity to touch. Second-degree chemical burns may take several weeks to heal and can leave scars.

c) Third-degree burns: This type of burn affects all layers of the skin, including underlying tissues. It is characterized by loss of skin, exposure of muscles and bones, and may be painless due to nerve damage. Third-degree chemical burns are severe and may require immediate medical treatment, such as skin grafting.

It is important to note that the severity of a chemical burn is not always evident immediately after exposure

to the chemical, and such classifications regarding depth may not have much significance. Sometimes, symptoms may take hours or even days to appear. Therefore, when establishing diagnostic criteria for chemical burns, it is done according to Wallace's Rule of Nines, which is a tool used to estimate the extent of a burn on the body surface. The Rule of Nines is commonly used in burn assessment and treatment planning.

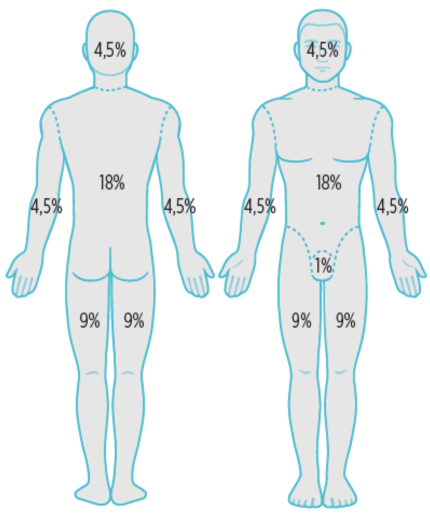
The Rule of Nines divides the body into sections, each representing approximately 9% of the total body surface area:

o Head and neck: 9%
o Each arm (including the hand): 9%
o Each leg (including the foot): 18% (9% for the front and 9% for the back)
o Chest (front): 18%
o Back (rear): 18%
o Genital region: 1%

For children and infants, the proportions vary slightly due to differences in body surface area distribution. For example, the head represents a larger proportion of the body surface area in a young child compared to an adult.

Fig. 2. Rule of Nines for calculating the affected surface area in burns.

Cabeza y cuello	9 %
Tronco	18 %
Espalda	18 %
Extremidad superior	9 % (x 2)
Extremidad inferior	18 % (x 2)
Área genital	1 %



It is important to remember that the Rule of Nines is only an estimation and may not be precise in all cases. However, it is a useful tool for quickly assessing the extent of a burn and determining the need for treatment, including potential chemical decontamination.

APPROACH IN THE WORKPLACE

Decontamination should be carried out rapidly and efficiently to minimize tissue damage and long-term complications. Collaboration between professionals in the workplace, such as physicians, nurses, and other specialists, is crucial to ensure a comprehensive and effective approach in the management of chemical burns.

The initial treatment of all chemical burns should aim to:

- Remove the product on the surface to prevent further penetration by using a flushing effect.
- Stop the chemical from further penetrating the affected tissues to halt the burning effect.

Washing and Decontamination

The initial approach to a person affected by a chemical contact should include general basic life support measures:

a) Assess the initial condition of the worker and provide basic first aid following the ABC (Airway, Breathing, Circulation) approach.
b) If assistance occurs in the same accident area, it is essential to assess the scene and apply necessary safety measures, prioritizing the safety of the assisting personnel without exposing them to risks.
c) Assess for signs and symptoms of inhalation burns or intoxication, as well as burns in the oropharynx and total circumferential burns in the neck, which will require early isolation of the airway.

Once the worker's general condition has been evaluated, decontamination treatment can be initiated:

1. Immediate Actions:

a) Enhance self-protection measures and, if possible, remove the toxic substance from the vicinity of the affected worker. The worker should immediately move away from the exposure area and request help by activating the emergency protocol.
b) If the chemical substance is in contact with the skin, contaminated clothing should be removed, and the affected skin should be washed with running water for at least 20 minutes. If safety showers are available, activate them and begin rinsing. Seeking medical attention as soon as possible is advisable.
c) If the chemical substance comes into contact with the eyes, flush the eyes with running water for at least 15 minutes.

2. Evaluation:

a) After immediate actions, assess the severity of the injury and determine if specialized medical attention is required.
b) If the injury is minor, decontamination can be performed at the workplace if medical assistance is available.
c) If the injury is severe, immediate specialized medical attention should be sought, and the appropriate workers' compensation organization should be contacted for surgical assessment.

3. Decontamination:

a) Decontamination should be carried out as soon as possible after exposure to the chemical substance, with a priority of starting within the first 5 minutes. It is important to note that this type of assistance is considered an urgent care.
b) Wash the exposed areas with abundant sterile saline solution (SS) or water to flush the chemical substance from the surface. It is recommended to continue washing for a minimum of 15 minutes, taking care not to induce hypothermia in cases of extensive injuries. It should be noted that while decontamination by washing with abundant water or SSF is used for virtually all chemical burns, there are some special situations in which this washing would be directly contraindicated, and efforts should be made to remove the chemical prior to washing. This occurs in cases of chemicals insoluble in water and cases of possible exothermic reaction when combined with water, such as:

- Calcium oxide or quicklime: reacts with water to form calcium hydroxide, a highly caustic alkali, so it is important to thoroughly remove the lime powder before washing with water.
- Concentrated sulfuric acid produces a significant amount of heat when combined with water, so it should be neutralized with soap before washing and then continue with a 15-minute wash.
- Phenol or carbolic acid: insoluble in water, and it is recommended to decontaminate with solubilizing agents such as 50% polyethylene glycol, isopropyl alcohol, or multipurpose solution.

c) If the chemical burn is associated with heat, the area should be cooled along with the decontamination process.
d) As an alternative to washing, if a DIPHOTERINE® device is available, it should be applied immediately, considering that its neutralizing effect is time-dependent. Its optimal effectiveness occurs when applied within the first minute. In the workplace, achieving its application within the first 5 minutes after chemical exposure can be considered acceptable. Thanks to its versatile activity, it allows for the management of special situations during the decontamination process, controlling the exothermic reaction. Providing symptomatic relief in the early stages is key to its proper application on the affected individual.
e) If it is a powder, it should be removed with a gentle sweeping system before irrigating the area or use Diphoterine in general.
f) Attend to other associated injuries and the patient's overall condition.
g) Depending on the type, extent, and general condition of the burn, consideration should be given to transferring the patient to a specialized burn unit in a hospital. The solution should be applied using a spraying device or by immersing the affected area in a container containing the solution.
h) Pay special attention to the risk of hypothermia during rapid and aggressive decontamination, where the chemical and thermal mechanisms are combined, as can occur with products like Waterjel®.

4. Decontamination with DIPHOTERINE®:

DIPHOTERINE® solution is a liquid designed for surface washing and is an alternative to traditional washing solutions. It is a hypertonic solution that, through osmotic effects, attracts the product that has penetrated the tissues outward. It contains chelating and amphoterics molecules that have the ability to stop each of the six possible types of reactions (acid, base, oxidation, reduction, solvation, chelation) (Lefrançois et al., 2014).

One of the fundamental advantages of DIPHOTERINE® solution is its versatility against the majority of chemicals used in the workplace (Tominaga, Jorden & Dubick, 2009). In the case of hydrofluoric acid, decontamination with HEXAFLUORINE® is recommended.

Decontamination with DIPHOTERINE® is performed by directly applying the solution to the skin and tissues affected by the chemical substance. The solution is applied using a micronized spray device over the body surface. The effectiveness of decontamination is time-dependent, meaning that its neutralizing outcome improves the sooner it is applied. However, its effectiveness also depends on the concentration of the chemical substance, the duration of contact, and the amount of exposed skin. Therefore, it is important to perform decontamination as soon as possible after exposure to the chemical substance.

In summary, decontamination with DIPHOTERINE® is an effective technique for neutralizing and eliminating chemical substances that cause chemical burns. It is important to perform decontamination as soon as possible after exposure to the chemical substance and seek immediate medical attention to assess the severity of the injury and provide appropriate treatment.

As examples of decontamination, the following videos are available:

Partial decontamination

Full body decontamination

5. Ocular Decontamination:

The decontamination of chemical splashes on the eyes is a critical aspect in managing ocular injuries caused by chemical agents. Due to the sensitivity of the ocular conjunctiva and its impact on the worker's life, the approach should be performed as quickly as possible:

a) Initial assessment: Quickly assess the severity of the ocular exposure and determine if immediate medical attention is required. If possible, obtain information about the chemical agent involved to guide the decontamination process.
b) Immediate irrigation: Begin irrigation of the affected eye as quickly as possible with water or sterile saline solution, preferably using an eyewash station if available in the workplace. This irrigation should be continuous and last at least 15 minutes, although longer irrigation may be necessary depending on the nature of the chemical agent. It is important for the patient to keep the eye open during the irrigation procedure.
c) Eyewash station: Whenever possible, use an eyewash station as it provides a constant flow of liquid and allows for more effective irrigation. If an eyewash station is not available, use an eyewash bottle or simply running water. If the DIPHOTERINE® eyewash solution is available, its use should be initiated in the early stages, following the instructions to blink while pouring the solution onto the affected eye.

d) Patient positioning: Position the patient in a way that facilitates rinsing and prevents the chemical agent from spreading to other areas of the body. For example, tilt the patient's head to the affected side so that the rinsing fluid flows downward and away from the unaffected eye and the rest of the body.
e) Medical evaluation: After completing the initial irrigation with water or DIPHOTERINE®, the patient should be evaluated by a medical professional to determine the need for additional treatment. This may include the administration of medications to control pain (topical anti-inflammatory), inflammation, or to restore ocular moisture that may remain after intense irrigation (artificial tears). As a general rule, a decrease in symptoms during irrigation that progressively allows the patient to blink is a positive sign.
f) Follow-up and monitoring: The patient should be followed up during and after the decontamination process to assess the effectiveness of the treatment and detect possible complications. Referral to an ophthalmology specialist should be considered if necessary. Long-term follow-up may also be necessary to evaluate the impact on ocular health and visual function.

As an example of ocular decontamination:

Eyewash decontamination

6. Special Chemical: Hydrofluoric Acid (HF):

Chemical burns caused by hydrofluoric acid (HF) are considered particularly dangerous and severe due to the following characteristic effects:

a) Rapid penetration: HF can easily penetrate the skin and underlying tissues, even through protective barriers such as gloves or clothing. This rapid penetration capability allows HF to cause deep damage even in small amounts.
b) Reaction with calcium: HF reacts by chelating the calcium present in the body, forming calcium fluoride, a salt that can precipitate and damage tissues. This chelation ability makes neutralizing HF more challenging, which can make treatment more difficult.
c) Delayed pain: Unlike other chemical burns, HF burns often do not cause immediate pain. This is because HF affects sensory nerves, causing neurological damage and delaying the perception of pain. As a result, victims may not be aware of the severity of the initial injury and delay seeking medical treatment.
d) Systemic effects: HF can be absorbed through the skin and lungs and then enter the bloodstream. This can lead to serious systemic effects such as kidney, cardiac, and bone damage. Exposure to high concentrations of HF can also cause respiratory effects and affect the cardiovascular system.

Due to these characteristic effects, chemical burns caused by hydrofluoric acid are considered particularly dangerous and require immediate medical attention. Prompt treatment is crucial to minimize damage and prevent serious complications by initiating early decontamination with water or specific solutions like HEXAFLUORINE® for more than 15 minutes if available.

7. Specialized Care:

a) After decontamination, specialized medical attention should be sought to assess the severity of the injury and provide appropriate treatment.
b) Treatment may include analgesics (e.g., paracetamol 500-650 mg/oral/6-8 h), anti-inflammatory drugs (e.g., ibuprofen 400 mg/oral/8 h), topical antibiotics (silver sulfadiazine), dressings, and other treatments depending on the severity of the injury.
c) Ongoing follow-up and continuous medical care should be provided to prevent complications in the first 24-48 hours.
d) If there are no respiratory injuries, burns that can be treated at primary occupational health centers should meet the following general criteria:

- First-degree burns with an extent of < 20% of the body surface.
- Second-degree burns affecting < 10%.
- Deep third-degree burns affecting < 1%.

More severe situations should be evacuated to a hospital for further treatment and assessment by a surgical specialist. This applies to burns affecting critical areas or individuals with chronic diseases susceptible to complications.

If you have any doubts regarding the type of chemical product and specific treatment, you can consult the National Institute of Toxicology and Forensic Sciences at their emergency toxicology hotline: +34 91 5620420.

Respiratory Care

As a consequence of acute exposure to chemical substances or their vapors, in addition to superficial chemical contact, respiratory tract injuries can occur (Henneberger & Kreiss, 2003), requiring urgent management by occupational medicine professionals.

1. Respiratory Tract Injuries from Chemical Vapor Contact:

a) Irritation of the respiratory tract: Inhalation of chemical vapors can cause irritation in the nose, throat, and lungs. Symptoms may include sneezing, coughing, sore throat, and difficulty breathing.

b) Chemical injuries to the lungs: Exposure to toxic chemical vapors can cause lung injuries such as chemical pneumonitis, pulmonary edema, and chemical bronchitis. These conditions can result in symptoms such as coughing, wheezing, chest pain, and difficulty breathing.

c) Chemical asphyxiation: Some chemical vapors can displace oxygen in the air, leading to asphyxiation and loss of consciousness. This can be potentially life-threatening if not promptly treated.

2. Specialized Medical Care:

a) Initial assessment: When receiving information about an incident of exposure to chemical vapors, conducting an initial assessment of the affected worker is crucial. This includes identifying the chemical involved, the duration of exposure, and the presence of respiratory symptoms. Select an optimal care space without exposure to risks. After stabilizing the ABC (Airway, Breathing, Circulation), proceed to evaluate external burns and the respiratory status.

b) Stabilization and treatment: Initial treatment may include administering oxygen, monitoring vital signs, and administering medications to alleviate respiratory symptoms. In severe cases, mechanical ventilation may be necessary.

i. Ensure airway patency by early isolation.
ii. Monitor: blood pressure, heart rate, respiratory rate, ECG, oxygen saturation (SatO2), carboxyhemoglobin levels, and temperature.
iii. Administer high-flow oxygen therapy with a reservoir mask in cases of respiratory insufficiency, with SatO2 < 92% or trending downward.

c) Decontamination: If a worker has been exposed to chemical vapors, it is important to ensure that proper decontamination has been performed to prevent further exposure.

d) Medical follow-up: Affected workers should be closely monitored for any complications or worsening symptoms. This may include pulmonary function tests and chest X-rays.
Facilities and Equipment:

Within the development of this guide, it is of interest to those involved in providing initial assistance to workers who suffer chemical burns within organizations and companies to establish key points in the application of this protocol regarding basic facilities and necessary equipment.

1. Identification and classification of chemical agents: It is essential to identify and classify the chemical agents involved to determine the most appropriate decontamination approach. This includes understanding the physical and chemical properties of the agents present in the work environment, as well as their effects on human health.

2. Adequate facilities: Victims of chemical exposure should be treated in facilities that are well-equipped to handle such emergencies. This may include the establishment of a dedicated decontamination room that is separated from other areas of the hospital or medical center to prevent cross-contamination and ensure patient safety. The decontamination room should have proper ventilation systems, an independent water collection system, emergency showers, and storage areas for personal protective equipment (PPE) (Fig. 3).

3. Personal protective equipment (PPE): Medical, nursing, and support staff involved in chemical decontamination should have appropriate PPE, such as protective suits, gloves, goggles, and masks. The PPE should be selected based on the specific chemical agent and the associated risk level.

4. Decontamination procedures: Decontamination procedures should be tailored to the specific chemical agent and level of exposure. This may include the removal of contaminated clothing, washing the skin and hair with appropriate solutions.

5. Training and education: Medical, nursing, and support staff should receive proper training and education on chemical decontamination protocols, including the identification of chemical agents, the use of PPE, and the implementation of decontamination procedures. Similarly, it is essential to emphasize the training of workers at risk of chemical contact to know how to act in the initial moments after suffering a chemical burn, the initial decontamination, and the request for specialized medical assistance in the workplace.

6. Research and development: Continuous research and development in the field of toxicology and chemical decontamination are essential to improve current protocols and practices. This includes the identification of new chemical agents, the development of

more effective treatments and antidotes, improvement of decontamination techniques, as well as the publication of scientific evidence on the effectiveness of decontamination protocols.

Fig.3. Image of a chemical decontamination room at SABIC Cartagena.

DOCUMENTATION OF INTEREST

• World Health Organization. Burns. 2021. Available at: https://www.who.int/news-room/fact-sheets/detail/burns

• Environmental Protection Agency. Chemical Safety. 2021. Available at: https://www.epa.gov/chemical-safety

• Occupational Safety and Health Administration. Chemical Hazards and Toxic Substances. 2021. Available at: https://www.osha.gov/chemical-hazards-toxic-substances

• National Institute of Statistics. Occupational Accidents. 2019. Available at: https://www.ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736177009&menu=resultados&idp=1254735573175

• Ministry of Health. Health Statistics. 2018. Available at: https://www.mscbs.gob.es/estadEstudios/estadisticas/estadisticas/estMinisterio/Sanidad2018.htm

• Occupational Risk Prevention Law. BOE núm. 269, November 10, 1995. Available at: https://www.boe.es/eli/es/l/1995/11/08/31/con

• European Chemicals Agency. REACH Regulation. 2021. Available at: https://echa.europa.eu/regulations/reach/understanding-reach

• SAMUR-Civil Protection Procedures Manual. https://www.madrid.es/ficheros/SAMUR/index.html

REFERENCES

- ECETOC. (s.f.). TARGETED RISK ASSESSMENT. https://www.ecetoc.org/tools/tra-main/

- Gülbitti, H. A., Cole, R. P., & Hewitt, J. (2017). Chemical burns: assessment and management. British Medical Journal, 356, j573. https://doi.org/10.1136/bmj.j573

- Henneberger, P. K., & Kreiss, K. (2003). Work-related reactive airways dysfunction syndrome cases from surveillance in selected US states. Journal of Occupational and Environmental Medicine, 45(4), 360-368. https://doi.org/10.1097/01.jom.0000058344.05741.8f

- Hettiaratchy, S., & Dziewulski, P. (2004). ABC of burns: pathophysiology and types of burns. British Medical Journal, 328(7453), 1427-1429. https://doi.org/10.1136/bmj.328.7453.1427

- Hettiaratchy, S., & Papini, R. (2004). Initial management of a major burn: II—assessment and resuscitation. BMJ, 329(7457), 101-103. https://doi.org/10.1136/bmj.329.7457.101

- INSST. (2012). AIP.203 RISKOFDERM - Risk Assessment of Occupational Dermal Exposure to Chemical Substances. Version 1.0. Retrieved from https://www.insst.es/documentacion/catalogo-de-publicaciones/aip.203-riskofderm-evaluacion-del-riesgo-por-exposicion-dermica-laboral-a-sustancias-quimicas.-version-1.0

- Kales, S. N., & Christiani, D. C. (2004). Acute chemical emergencies. New England Journal of Medicine, 350(8), 800-808. https://doi.org/10.1056/NEJMra030639

- Lefrançois P, Goujon JM, Andary M, et al. Diphoterine® solution: a new concept in chemical skin decontamination. Burns. 2014;40(4):734-740. doi:.1016/j.burns.2013.09.019

- López Gutiérrez JC, Sánchez Delgado J, Pérez Blázquez E, et al. Quemaduras químicas en un hospital de tercer nivel. Experiencia de 10 años. Cir Esp. 2017;95(2):84-91. doi:10.1016/j.ciresp.2016.06.017

- Mowad, C. M. (2016). Occupational dermatitis. In: Bolognia, J. L., Schaffer, J. V., & Cerroni, L. (Eds.), Dermatology (4th ed., pp. 289-298). Elsevier. https://doi.org/10.1016/B978-0-7020-6275-9.00029-1

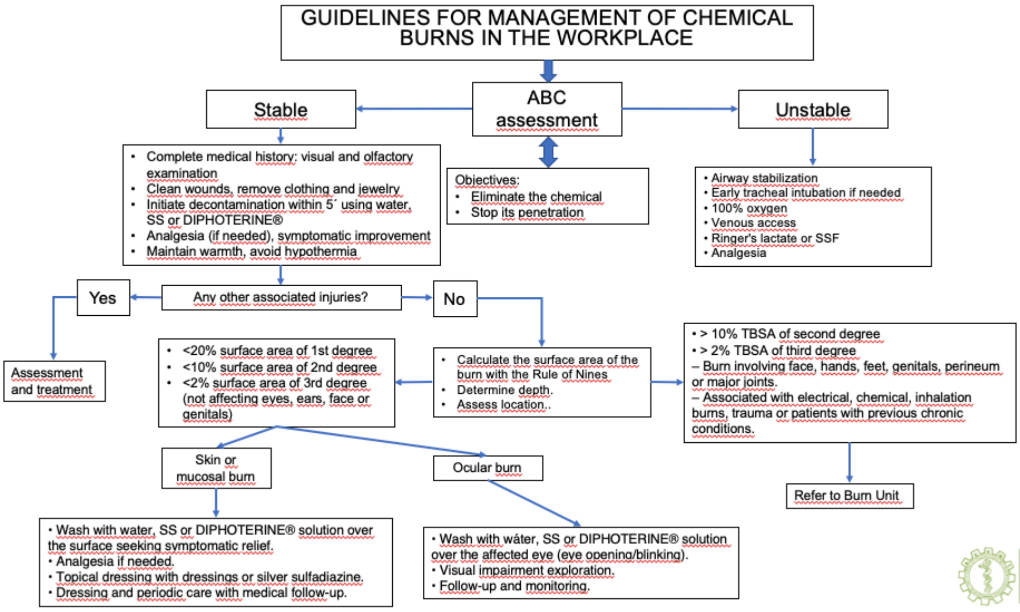
- Pérez C, González C, Molina J, et al. Epidemiología de las quemaduras: estudio en la Comunidad Valenciana. Cir Esp. 2008;84(4):207-212. doi:10.1016/S0009-739X(08)70238-8

- Rastogi, S. K. (2008). Occupational chemical burns: a 2-year experience in a large chemical company. Burns, 34(7), 1035-1038. https://doi.org/10.1016/j.burns.2008.01.012

- Rodríguez J, Arroyo A, Bernal A, et al. Caracterización de las quemaduras por agentes químicos en el ámbito laboral. Med Segur Trab. 2010;56(218):49-58

- Tominaga GT, Jorden RC, Dubick MA. Diphoterine for chemical burns: a case report and review of the literature. Prehosp Emerg Care. 2009;13(4):541-546. doi:10.1080/10903120903039656

ANNEX


GUIDELINES FOR MANAGEMENT OF CHEMICAL BURNS IN THE WORKPLACE
ABC assessment
Stable
Unstable
Objectives:
• Eliminate the chemical
• Stop its penetration
• Complete medical history: visual and olfactory examination
• Clean wounds, remove clothing and jewelry
• Initiate decontamination within 5´ using water, SS or DIPHOTERINE®
• Analgesia (if needed), symptomatic improvement
• Maintain warmth, avoid hypothermia
• Airway stabilization
• Early tracheal intubation if needed
• 100% oxygen
• Venous access
• Ringer's lactate or SSF
• Analgesia
Any other associated injuries?
Yes
No
Assessment and treatment
• <20% surface area of 1st degree
• <10% surface area of 2nd degree
• <2% surface area of 3rd degree (not affecting eyes, ears, face or genitals)
• Calculate the surface area of the burn with the Rule of Nines
• Determine depth.
• Assess location..
• > 10% TBSA of second degree
• > 2% TBSA of third degree
– Burn involving face, hands, feet, genitals, perineum or major joints.
– Associated with electrical, chemical, inhalation burns, trauma or patients with previous chronic conditions.
Refer to Burn Unit
Skin or mucosal burn
Ocular burn
• Wash with water, SS or DIPHOTERINE® solution over the surface seeking symptomatic relief.
• Analgesia if needed.
• Topical dressing with dressings or silver sulfadiazine.
• Dressing and periodic care with medical follow-up.
• Wash with wáter, SS or DIPHOTERINE® solution over the affected eye (eye opening/blinking).
• Visual impairment exploration.
• Follow-up and monitoring.