**emergencias** 2007;19:323-336

**Review Article**

# Healthcare actions in terrorist attacks chemical war fare agents: more than 10 years after the attacks sarin in Japan (Part 1)

**R. Pita[1], S. Ishimatsu[2], R. Robles[3]**

[1]Escuela Militar de Defensa NBQ. Ministerio de Defensa. Hoyo de Manzanares. Madrid. [2]Servicio de Urgencias. St. Luke's International Hospital. Tokio. Japón. [3]Responsable de Catástrofes del SUMMA 112. Madrid.

## ABSTRACT

After the September 11 (2001) terrorist attacks in the USA and the subsequent mailing of letters contaminated with *B. anthracis* spores, a high perception of risk has become noticeable regarding the possibility of attacks with weapons of mass desctruction, particularly by groups associated to the Al Qaeda terror network. For this reason, the medical personnel –both extra- and intrahospitalary– has become concerned about how to act and perform in this type of events. In the case of chemical warfare agents, the guiding principles of medical support are based on the experiences and on the lessons learned by the personnel that dealt with the sarin terrorist attacks in Japan in 1994 and 1995. The present paper aims at delving deeper into these lessons and findings of over ten years ago, bearing in mind that any and every medical service and organisation should adapt them to their particular environment, situation and characteristics.

**Key Words:** *Chemical terrorism. Chemical warfare agents. Emergency medicine. Decontamination.*

## RESUMEN

### Actuación sanitaria en atentados terroristas con agentes químicos de guerra: más de diez años después de los atentados con sarín en Japón (1ª parte)

Tras los atentados del 11 de septiembre de 2001 en EE.UU. y, sobre todo, desde los envíos de sobres con esporas de carbunco, existe una alta percepción del riesgo sobre posibles atentados con armas de destrucción masiva por grupos asociados a la red terrorista Al Qaeda. Esto ha llevado a que el personal sanitario extrahospitalario y hospitalario se interese sobre cómo debería ser su actuación en este tipo de incidentes. En el caso particular de los agentes químicos de guerra la base de la actuación sanitaria son las lecciones aprendidas por el personal sanitario que participó en los atentados terroristas con sarín que tuvieron lugar en Japón en 1994 y 1995. El presente trabajo intenta profundizar en estas lecciones aprendidas hace ya más de diez años, teniendo en cuenta que será cada servicio y organización sanitaria el que deberá adaptarlas a su situación y características particulares.

**Palabras clave:** *Terrorismo químico. Agentes químicos de guerra. Medicina de emergencias. Descontaminación.*

## INTRODUCTION

The first chemical warfare terrorist attack took place in the Japanese city of Matsumoto on the 27th of June of 1994. On that day a legal religious organization, Aum Shinrikyo, sprayed sarin neurotoxic gas killing 7 people and intoxicating another 600[1]. On the 20th of March of 1995 a second sarin gas attack on the Tokyo underground system killed 12 people and led to more than 5,000 to seek medical care in the city's hospitals. Furthermore, between the two attacks, Aum Shinrikyo carried out four other attacks with another neurotoxic agent, VX, directed towards private individuals deemed to be enemies of the organization. Only one of these 4 attempts was successful in killing the person under attack[2]. These attacks meant that the worst fears of the nuclear, biological and chemical (NBC) defence community on the non-military use of chemical weapons had come true. A few years back the attacks by some terrorist organizations to obtain these types of weapons had alerted experts in the field[3,4] hitherto geared towards the protection of troops from military use of such

**Correspondence:** René Pita
Escuela Militar de Defensa NBQ.
28240 Hoyo de Manzanares (Madrid)
E-mail: renepita@arrakis.es

Received: 12-6-2006
Accepted: 6-6-2007

agents. Nevertheless, this concern had no significant repercussion in the public and government arenas, perhaps because the use of chemical weapons by a religious organization in Japan seemed remote from the everyday reality of the rest of the world. All this changed after the September 11th attacks in the USA (9/11) and more so following the discovery of mailed envelopes containing anthrax spores in that country. Despite the low number of anthrax victims compared to the attack in Japan, the assumed military origin of the anthrax used and its possible connection with those responsible for the 9/11 attacks spread panic and fear around the world of a possible attack with weapons of mass destruction by groups linked with the terrorist group Al Qaeda.

Since then considerable interest in chemical warfare agents has been shown among the medical sector, which has led to an increase in the number of papers published in biomedical journals and health courses describing these agents, their action mechanisms and how to treat intoxications (Table 1). These are mostly based on military manuals and publications from the US and the North Atlantic Treaty Organization (NATO) adapted to civil scenarios. Likewise, most of them refer to the lessons learned from the attacks in Japan. The recommendations could be said to bear some similarity with those learned in several incidents that medical personnel has had to deal with involving industrial chemicals. Each incident yields new lessons which, unfortunately, highlight the need to apply the lessons learned in previous incidents. In fact, despite the high perceived risk regarding the possible use of weapons of mass destruction in terrorist attacks, the pictures of the attacks of the 7th of July 2005 in London showed the first personnel arriving at the underground stations wearing no protection of any kind, when it had not yet been confirmed that only conventional explosives had been used.

In direct contrast to an attack with conventional weapons, in an attack with chemical warfare agents the nature of the agent used may not be known at the start; in this case, the handling of the victims will require special protection measures to prevent the medical personnel from becoming victims themselves and, in some cases, the treatment of the intoxication may involve the use of specific antidotes. After the 9/11 attacks, a study published in Spain in 2002 drew attention to problems with the availability of antidotes in the event of a chemical warfare attack[5], whereas another study published in 2003 indicated a low perception of the level of preparedness of Emergency medical personnel in Catalan hospitals in the event of having to deal with an attack by chemical weapons of mass destruction[6].

This paper examines the lessons learned from the medical intervention in Japan and other chemical agent incidents to thereby reduce the consequences, in the event of an attack

**TABLE 1. Main "classical" chemical warfare agents and other chemical substances of possible use in terrorist attacks**

| Group of agents | Main examples | Action mechanism | Antidotal treatment |
|---|---|---|---|
| Neurotoxic agents | Sarin, soman, tabun and VX | Acetylcholinesterase inhibition | Atropine, oxime[a] and benzodiazepine[b] |
| Vesicant agents | Nitrogen and sulfur mustards (eg. Yperite), lewisites and phosgene oxime | Alkylation of different molecules[c] | Against lewisites: BAL, DMPS or DMSA |
| Pneumotoxic agents | Chlorine, chloropicrine, phosgene, diphosgene and perfluoride isobutylene | Irritation of respiratory passage and/or acylation of proteins regulating permeability or alveolar membrane | Unavailable |
| Cyanide agents | Cyanhydric acid and halogen cyanogens | Inhibition of mitochondrial cytochrome oxidase | Hydroxocobalamine or sodium nitrite and sodium thiosulfate |
| Other agents: incapacitators[d], riot control, bioregulators, toxins and industrial chemicals. | | | |

[a]Pralidoxime, obidoxime and Hl-6 are the main commercially available oximes.
[b]Given that the medium to long term action mechanism of neurotoxic agents included the GABAergic system, its administration is recommended even in the absence of convulsions.
[c]The action mechanism of phosgene oxime is unknown.
[d]During the Cold War era, various countries examined the possibility of using substances acting on the central and peripheral nervous systems as weapons. The main example is BZ, a centrally acting anticholinergic agent.
BAL: dimercaprol. DPMS: 2.3-dimercapto-1-propanosulfonic acid. DMSA meso 2.3-dimercaptosuccinic acid.

with chemical warfare agents, by more effective action taken by medical personnel.

## OPERATIONAL COORDINATION

In any terrorist attack the management of the crisis must entail the coordination of all intervening bodies to optimize the available resources[7-9], which includes an Operational Coordination Centre (OCC) led by an Advanced Command Post (ACP) with its own action groups. Effective coordination will reduce the likelihood of over-triage, that is, casualties who do not require immediate treatment being taken to hospital at the risk of causing saturation and endangering those more seriously affected. The transport of victims to hospital should be perfectly coordinated among the various hospitals in the area, taking into account the proximity and capacity of the centres, to attain a more balanced distribution[10]. In the sarin attack in the Tokyo underground, the hospital that attended the highest number of victims was the St. Luke International Hospital, located at 500 metres from the metro station of Tsukiji, one of the most affected[11]. On the 20th of March of 1995, the day of the attack, this hospital attended 641 patients and an additional 349 over the next 7 days. Only 7% of the victims arrived by ambulance, but rather did not originate from the Tsukiji station but that of Kodenma-cho, located 3 km. from the hospital, as a direct result of the lack of coordination in the transport of victims[12,13].

During the Iran-Iraq war, the Iranian attack with neurotoxic agents on the city of Hosseiniyeh in 1987 caused around 300 seriously injuried victims to be taken to the closest Iranian military medical unit in the first 5 minutes, followed by another 1,700 less seriously affected victims, causing the collapse of this unit; this was added to the absence of any distribution plan of referral to other medical centres[14]. More recently, in September 2001, an explosion at an ammonium nitrate fertilizer plant in the French city of Toulouse caused 30 fatalities, more than 2,200 wounded by the mechanical and thermal effect of the explosion, and more than 5,000 persons treated for stress, with the ensuing collapse of the emergency departments of some hospitals due to mild casualties arriving spontaneously by their own means[15,16]. Similarly, during the terrorist attacks in Madrid on the 11th of March, 2004 (11M) over-triage occurred in the transport of victims to the University General Hospital Gregorio Marañón[17,18].

Operational coordination should also help mobilize any medical resources that may be required, as well as the coordination of all bodies involved at a tactical level. In fact, the lack of coordination observed among the intervening bodies in 9/11 and the incidents with anthrax letters in the USA have highlighted this aspect as one of the most significant lessons learned[19].

As shall be explained shortly, the detection or identification of the agent by the personnel first arriving on the scene can be complicated and may require samples to be sent for laboratory analysis. Once identified, medical personnel should be informed of the agent begin or continue with the appropriate antidotal treatment within 3 hours. St Luke's Hospital knew that the police had identified sarin gas as the agent, but neither via the coordination centre nor the police, but via television[12]. Operational coordination should prevent such situations from happening.

Finally, drills, simulations and serious mock attacks should be put into practice in order to confirm the existence of the required coordination to handle a chemical warfare attack and to learn further lessons[20,21].

## PERSONAL PROTECTION EQUIPMENT (PPE)

One of the main lessons learned from the sarin gas attacks in Japan is the need for all personnel entering the area affected by the chemical agent, or in contact with the non-decontaminated victims, to wear appropriate personal protective ensembles[22]. The EEC directive 89/656 of the 30th of November of the European Community Council (assimilated into Spanish law by Royal Decree 773/1997 of the 30th of May) sets forth the "minimum health and safety provisions in the selection, use by employees at work and maintenance of the PPE's", but excludes PPE's from aid and rescue, military, police and peacekeeping services. On the other hand, EEC Directive 89/686 of the 21st of December (assimilated into Spanish law by Royal Decree 1407/1992 of the 20th of November and subsequent amendments) sets forth the essential minimum requirements to be fulfilled by PPE's, thereby regulating the conditions under which PPE's are marketed and traded within the EEC. Moreover, it established the essential requirements for health and safety to be fulfilled by all PPE's. Its Appendix I states that "PPE's specifically designed and manufactured for the Armed Forces, public order bodies and those for self-defence against assault (eg. Aerosol devices and personal deterrent weapons)" are excluded from the scope of action governed by the Directive. Nevertheless, these requirements have given rise to a series of European Regulations (ERs) issued by the European Committee for Standardization (ECS), as well as the domestic equivalent (SCS), on breathing protection equipment and protective clothing, gloves and footwear against chemical products which could be extended to the

NBC protective equipment or, if applicable, to protective wear against chemical warfare agents. Furthermore, despite the absence of a European classification of PPE's against chemical disasters or attacks, the EEC Directive 89/686 classifies them as category 3 PPE's, that is, those of "complex design, made to protect the user from all mortal hazard or which may seriously and irreversibly damage health".

PPE's used in NBC situations are usually classified according to the 4 protection levels set forth by the Environmental Protection Agency, EPA[23,24]. (Table 2) (Figure 1). This classification is also used by the Spanish National Toxicological Institute[25]. The EPA classification must not be mistaken with the classification of protective ensembles for chemical/biological terrorism incidents issued by the US National Fire Prevention Association (NFPA), often used but lacking respiratory protection[26] (Table 2). Level A in the EPA classification is the highest protection for the respiratory system, skin, eyes and mucosae. It consists of a totally encapsulated and airtight suit, resistant to chemical substances and fitted with an autonomous full mask breathing device. The self-contained breathing equipment has a connection with a source of compressed air and may be open circuit – when exhaled air is issued out to the open air- or closed circuit – when exhaled air is recycled by a filter regeneration system which fixes carbon dioxide and is equipped with an independent oxygen supply. In chemical incident interventions the most commonly used and most appropriate systems are the open circuit systems with positive pressure, that is, those into which the air enters the mask creating a positive pressure (higher than the outside), giving additional protection in the event of a leak. Likewise, open circuit equipments with possible pressure on demand, also known as "pressure on demand", in which the airflow to the mask increases with inhalation are also recommended. The disadvantages of self-contained breathing equipments are their weight, impaired mobility in small spaces and that the time spent in the affected area is restricted to the supply of compressed air. Level B is similar to level A, except that the suit is not encapsulated or airtight. The intervening personnel entering a chemically affected zone for the first time should wear the highest protection possible, preferably level A, but in no case a level of protection lower than level B[23,24].

In Level C dermal protection is similar to that of Level B but the protection of the respiratory system is lower, as it uses a full mask with a gas filter which prevents the entry of certain chemicals by chemical reaction, adsorption or absorption. There are different classes and types of commercially available filters and the ER's have established a colour-coding system to indicate the chemical substance or substances against which they are to be used[27,28] (Table 3).

The filters are specifically designed for certain chemical substances and for certain concentrations, usually a level under the concentration Immediately Dangerous to Life or Health (IDLH), that is, concentrations which, in the event of exposure, should not produce effects or symptoms which would prevent the person from escaping, as well as no risk of immediate death, long term or irreversible effects. This level of protection should not be used if the identity or concentration of the chemical substance is unknown, and no data indicates whether the oxygen level is below 17-19.5%[24-29]. There are assisted filtering systems (or of assisted ventilation) in which an engine-powered ventilator pushes the air through a filter and sends it towards the facial mask, thus assisting breathing via low inhalation resistance and increasing the mask's level of protection[30,31]. It is important to note that the batteries for such systems can shorten the time they can function at low temperatures. The ERs establish that a fully charged battery should last for at least 4 hours[29]. The useful life of an anti-gas filter will depend on its filtration capacity, the concentration of the agent, air temperature and moisture and the user's breathing rhythm. Devices based on colorimetric reactions as indicators of filter saturation levels are currently being explored.

It is important to bear in mind that the filters of military NBC masks are designed only to prevent contact with 'classical' chemical warfare agents (neurotoxic, vesicant, pneumotoxic and cyanide) (Figure 2). In fact, the activated carbon in such filters would not be capable to adsorb the cyanide agents without special treatment with copper or chromium salts, which form copper or chromium cyanide, thus preventing inhalation by the user. These military NBC filters are of the combined type, incorporating HEPA (High Efficiency Particulate Air) filters as well as the carbon activated filter, with an efficacy of at least 99.997% against 0.3-0.4 µm spray particles, with a dramatic increase in efficacy against larger particles. The filtering efficacy of these HEPA filters[32-36] is therefore higher than that required by the ERs from high efficacy particle filters in full masks (P3), which is 99.95% with sodium chloride sprays with an average mass aerodynamic diameter of 0.6 µm and liquid paraffin of average Stokes diameter of 0.4 µm[37-39]. HEPA filters are usually arranged in folds, seeking to increase the filtration surface and reduce resistance against inhalation.

Protective clothing against chemical agents according to the ERs is classified into 6 types[40-45] (Table 2). In order to help select the clothing, it is important that the manufacturer provides information on the mechanical resistance and resistance to the permeation and penetration of different chemical substances according to the ERs[46,47], although some manufacturers also provide this information in accordance with the regulations

**TABLE 2. Classification of personal protection equipment (PPE) against chemical agents**

| Classification of the levels of personal protection against hazardous chemical substances issued by the Environmental Protection Agency EPA[23,24] | | | |
|---|---|---|---|
| **Protection level** | **Recommended breathing protection** | **Recommended dermal protection** | **To be used when** |
| A | Autonomous insulating equipment with full mask and pressure-demand supplied aira | Encapsulated wear, airtight to gas/vapour chemical agents and resistant to liquid chemical agents. Internal and external gloves, as well as footwear, must also be resistant to chemical agents. | - Maximum protection is required against chemical agents in gas/vapour or liquid form |
| B | Autonomous insulating equipment with full mask and positive pressure on demand[a] | Equipment resistant to chemical agents in liquid form. Internal and external gloves, as well as footwear, must also be resistant to chemical agents. | - Identity and/or concentration of chemical agent is unknown. In the event of suspected high risk of exposure to high concentrations of vapour or gas with noxious results for the skin, level A protection should be used.<br>- The physical-chemical characteristics of the agent prevent the use of protective breathing apparatus with filter device (level C)<br>- The concentration of the agent is higher than or equal to the IDLH concentration and protective breathing apparatus with filter device (level C) cannot be used<br>- The air contains less than 19.5%[b] oxygen and protective breathing apparatus with filter device (level C) cannot be used |
| C | Equipment with full mask filter device | Equipment resistant to chemical agents in liquid form. Internal and external gloves, as well as footwear, must also be resistant to chemical agents. | - The identity and concentration or the agent are known and do not exceed the IDLH and air contains at least 19.5% oxygen |
| D | None | Normal work wear | - Must not be used in chemical incidents |
| **Standard of protective ensembles for chemical/ biological terrorism incidents from the National Fire Protection Association, NFPA[26]** | | | |
| **Class[c]** | **Protective ensemble[d]** | **Must be used when risk analysis indicates that:** | |
| 1 | Against agents in gas/vapour form (airtight wear) and liquid form | - Identity or agent or concentration of gas/vapour or liquid is unknown.<br>- Contact with agent in liquid form is expected in hot zone. Lack of protection would mean a high possibility of immediate death, immediate serious incapacitation or incapacity to escape. | |
| 2 | Against agents in liquid form and lesser protection against agents in gas/vapour form than in Class 1 | - The victims in the hot zone show symptoms and are not ambulant<br>- Possibility of direct contact with agent in liquid form | |
| 3 | Against agents in liquid form | - The victims in the hot zone show symptoms and are ambulant<br>- Possibility of contact with agent in liquid form | |

**TABLE 2. Classification of personal protection equipment (PPE) against chemical agents (cont.)**

| Types of protection ensembles against chemical products according to European Regulations (ER)[40-44] | |
|---|---|
| **Type** | **Characteristics of protection** |
| 1 | Airtight wear with breathing air supply[e] |
| 2 | Non-airtight wear with breathing air supply |
| 3 | Wear with watertight seams |
| 4 | Wear with spray-tight seams |
| 5 | Wear with protection against solid particles |
| 6 | Wear offering limited protection against liquid chemicals |

[a]The EPA recommends, as an alternative, the use of insulating breathing protection with self-contained compressed air supply on demand. This makes it cumbersome and impractical for intervention in chemical terrorism incidents.
[b]The EPA establishes an oxygen concentration of 19.5% as the threshold for deciding on the use or not of breathing apparatus fitted with a filter device, whereas the European regulations set this limit as 17%.
[c]For each category a series of permeation and penetration tests of chemical warfare agents have been carried out, with agents such as sarin gas, VX, distilled yperite and lewisite, as well as various industrial chemicals.
[d]No breathing protection equipment requirements have been established for any of the 3 classes
[e]They can simultaneously wear breathing protection equipment within the suit (type 1a), outside the suit (type 1b) or a connection with a breathable air tube (type 1c). There are type 1a and 1b emergency protection suits, 1a-ET and 1b-ET, respectively, with special requirements[45].

of the American Society for Testing and Materials (ASTM). However, it must be taken into account that real life working conditions will yield values that are different to those obtained from laboratory tests when assessing risk[48]. Such values can help to compare materials, always bearing in mind that they have been obtained under controlled testing conditions set forth by the ERs or the ASTM regulations. In reality the suits, gloves and footwear lose efficacy through use. The contact with the ground, the flexure and stretching of the gloves and footwear reduce the thickness in the affected areas, thus reducing protective capabilities[48-51]. Temperature may also affect the PPEs properties. For instance, standardized testing


**Figure 1. Levels of personal protection against hazardous chemical substances according to the US Environmental Protection Agency[23,24].**

**TABLE 3. Types of filters for gases according to the European Regulations (ERs)[27,28]**

| Type[a,b,c] | Use | Colour code (marked) | Special features |
|---|---|---|---|
| A | Against certain organic gases and vapours with boiling point >65ºC | Brown | |
| B | Against certain inorganic gases and vapours | Grey | |
| E | Against sulphur dioxide and other acid gases and vapours | Yellow | |
| K | Against ammonium and organic ammonium derivatives | Green | |
| AX | Against certain organic gases and vapours with boiling point ≤65ºC | Brown | Non-reusable or single-use filters |
| SX | Against specific gases and vapours | Violet | Information should indicate chemical product names and maximum concentrations for which filter is efficacious |
| Special filters: | | | Includes high efficacy particle filter (P3) |
| NO-P3 | Against nitrogen oxide | Blue-white | Non-reusable or single use filters |
| Hg-P3 | Against mercury | Red-white | Maximum length of use of 50 hours |

[a]A,BE and K filter types are classified according to capacity into class 1 (low capacity), class 2 (medium capacity) and class 3 (high capacity). The capacity test according to the ER uses different saturation concentrations according to the class of filter.

[b]Multiple filters are those with combinations of two or more types (excluding SX type).

[c]Combined filters are those which also incorporate a particle filter (eg. ABEK 1-P3). The air always passes first through the particle filter. The colour code should include white pertaining to the particle filter (P).

**Figure 2. The intervening personnel to first enter the area where the chemical incident has taken place must wear the maximum possible protection, including self-contained breathing equipment. Once the identity and concentration of the agent is known, as well as the oxygen concentration level, the level of personal protection may be reduced. The picture shows an NBC defence unit carrying out a reconnaissance mission in Iraq. They were fortunately wearing level A protection with self-contained breathing devices when the nitric acid (used as a propellent in some Iraqi missiles) was leaked. If personnel had been wearing military NBC masks they would have possibly already been intoxicated, as nitric acid is not adsorbed by the activated carbon in the NBC mask filters.**

temperature for determination of resistance to permeation (breakthrough time) by chemicals of protective gloves is 23ºC[52] and it has been observed that the temperature on the inside of the glove increases with body temperature[53]. It has been concluded that changes in the outer and inner temperature of a glove lead to significant changes in penetration and permeation times of gloves made of different materials and exposed to different chemical substances[53]. A well-known example in the field of toxicology regarding the importance of expert interpretation of the properties of protective materials has been the death of Dr. Karen E. Wetterhahn in 1997 when "a few drops" of dimethylmercury fell on one of her gloves[54] A poor assessment of risk and insufficient data or the protection offered by the glove manufacturers against this substance led to this fatality. Butyl gloves and boot covers provide better protection than those made of nitryl against 'classical chemical warfare agents[55], but in an attempt to obtain a better range of protection against an unknown hazardous substance, the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) recommends the use of butyl external gloves of 14 milli-inches and internal nitryl ones measuring 4-5 milli-inches[56].

The use of PPE poses significant problems for the user. The use of respiratory protective devices may have pulmonary repercussions (increase in the anatomical dead space, increase in respiratory resistance- inhalation and exhalation, and alteration of respiratory parameters), cardiovascular effects (increase in heart rate, higher blood pressure and reduction in capacity to resist physical exertion), psychological, dermal (in contact areas and pressure points), postural (due to the weight of the autonomous systems), ophthalmologic (reduction of visual field) and reduced auditory perception, impairing communication[31,57-72]. The materials of the PPE hinder the good functioning of the mechanisms of heat loss through the conduction, convection, radiation and, especially, the evaporation of swee[73-75]. In a study carried out on the NBC PPE of the US Army, it was observed that its use is matched with a 5.5ºC increase in the WBGT (Wet Bulb Globe Temperature) index[76], used in the assessment of thermal stress[77]. The risk of thermal strain is therefore increased with alternations in the central nervous system due to the failure of the thermo-regulating system, running the risk of death due to multiple organ failure[78]. Lighter PPEs are available on the market, enabling transpiration and which are resistant to certain ranges of chemical substances. PPE have also been developed with cooling systems which, compared to conventional equipment with no cooling, successfully reduce peripheral body temperature and the speed of increase of central body temperature[73,74]. Military NBC masks are fitted with a liquid ingestion system which enables rehydration of the soldier[79]. Regarding the gloves, the increase in thickness increases degree of protection but reduces the person's dexterity and agility: in the case of medical personnel, for instance, when feeling a pulse, finding a vein or intubing a person[80-83]. In these cases USACHPPM recommends using 7 milli-inch butyl gloves on nitryl gloves, or only 14 milli-inch butyl gloves.

Given the problems mentioned regarding the use of PPEs, it is understood that only personnel in good health who have received appropriate training should intervene in incidents requiring their use[58,84-86], particularly when the use of autonomous respiratory devices is requried[31]. In the USA, the Occupational Safety and Health Administration (OS-HA) requires minimum levels of training on PPEs for the personnel intervening in hazardous substance incidents[23]. Moreover, it has been shown that PPE training programmes increase efficacy of use[87]. The correct use of a PPE also depends on good user fitting and correct maintenance[48]. Manufacturers may, in some cases, offer different sizes but special fitting is vital, as a small maladjusted space may be enough to allow the entry of contaminated air. Several tests exist to ensure the correct fitting and airtightness of the masks[31,88,89]. Facial hair may reduce the level of protection by increasing the risk of leaks if it should get trapped in the airtight edges, that is, between the face and the facial device[84]. Prescription eyeglasses should be compatible with the respiratory protective devices but no tests are necessary as this does not present a risk of leakage, that is, a lack of airtightness[31,86].

Ideally, the best PPE should be chosen according to the identity and concentration of the chemical agent so as to obtain good protection whilst allowing the user the highest possible degree of agility and mobility. However, in the event of a terrorist attack this may not be possible and, for logistical and practical purposes, the storage of different PPEs for one same user to use for each specific occasion would not be feasible[90].

## CHEMICAL AGENT DETECTION AND IDENTIFICATION EQUIPMENT

The main commercially available systems for detection and identification of hazardous substances are based on enzymatic and colormetric reactions, ionic mobility spectrometry (IMS), photoionization (PI), flame photometry (FP), gas chromatography-mass spectrometry (GC/MS), infrared spectroscopy (IR) and surface acoustic waves (SAW)[91]. All these systems, regardless of the technology used, yield a number of false positives and/or false negatives due to their sensitivity

and selectivity[92]. It is important that the personnel using the detection and identification devices understand how these work and the possibility of yielding false responses. The physical and chemical properties and meteorology may affect the response, so that only a good knowledge of the equipment and chemical agents will enable interpretation of the results. Alarms for false positives happen when the equipment indicates the presence of the chemical agent, when it is in fact absent. A false positive can occur for a number of reasons, depending on the basis for the technique used. For instance, any compounds containing phosphorous and sulphur, such as some insecticides, could yield false positives in warfare hazardous substance detectors based on FP, as FP detectors respond to any compounds contained in phosphorous and sulphur (Figure 3a). False negatives happen when the equipment does not respond in the presence of the chemical agent (Figure 2b). Like false positives, a false negative can be the result of different factors depending on the technique used: low sensitivity, changes in meteorological conditions, humidity, interference of chemical substances, a limited number of chemicals in the recognition library or algorithmic deviations. All equipment is usually designed to achieve a balance between false positives and false negatives, in an attempt to reduce errors to the minimum, although this may have some limitations in practice. In a terrorist attack false positives lead to the unnecessary use of PPE which reduce the operative capacity of the intervening personnel. However, false negatives are even more dangerous, as they may lead to exposure of the personnel to the chemical agent. This is why false positives are less problematic than false negatives in the detectors used by the first personnel on the scene[92,93].

The lessons learned from the Aum Shinrikyo attacks in Japan include the importance of false positives in a real life scenario. The Tokyo firefighters initially reported a conventional explosion in the underground, only to report an hour later on an incident involving acetonitryl, which was eventually found to be a false positive in their detector equipment[11,12]. It was not until 3 hours after the attack that the police was able to detect sarin gas via GC/MS. Fortunately medical personnel had already begun administering the appropriate antidotal treatment based on the clinical signs of the intoxication such as miosis, rhinorrhea and low levels of blood cholinesterase.

In 1986 some 48 Iranians intoxicated with yperite (mustard gas) were transferred to London for treatment. On arrival they were monitored at the airport with IMS equipment and 5, who had been exposed to yperite 6-8 days before, yielded a positive result for yperite. The reason was an equipment false positive[94], as yperite, due to its rapid absorption and reactivity, is not detected 30 minutes after dermal contact[95].

Detection also plays an important role in decontamination

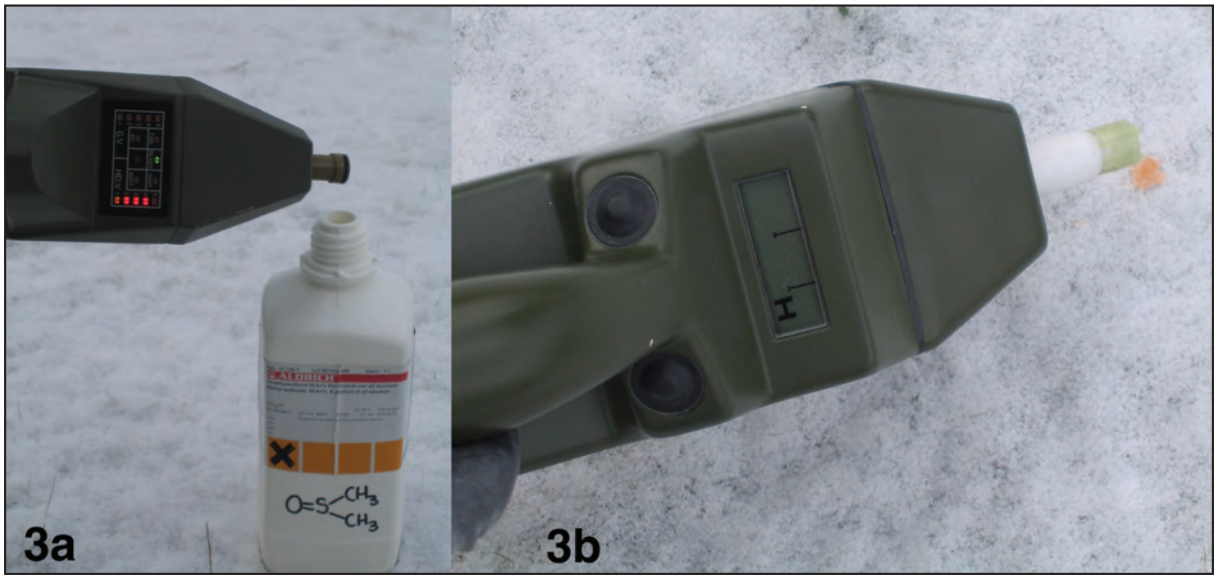


**Figure 3a. Example of a false positive, Dimethyl sulphoxide (DMSO) is a commonly used organic solvent. Its structure, like that of yperite, includes a sulphur atom. The detection equipment in the picture is based on flame photometry and responds to any substance containing sulphur or phosphorous in its structure, yielding a false positive of warfare vesicant agent in the presence of DMSO. Figure 3b. Example of a false negative. At low temperature, the steam pressure of the yperite is reduced and the detector in the picture, based on ionic mobility spectrometry, is unable to detect it, yielding a false negative.**

processes, as detection systems are normally used to verify the efficacy of the decontamination process. A false negative may lead to a bad decontamination process appearing correctly performed.

In addition to the economic effort that the purchase of detection and identification equipment entails, these also require regular maintenance, even weekly in some cases. Poor maintenance will render them ineffective, thus affecting the entire intervention.

## DIFFERENTIAL DIAGNOSIS AND TRIAGE

Differential diagnosis should allow medical personnel to identify the agent causing the toxic syndrome based on a number of clinical signs that are easily recognised, particularly in the case of a high number of victims, bearing in mind there are many substances that can produce symptoms and clinical signs similar to "classical" chemical warfare agents[93,96]. For example, in 1997 a US Army unit believed it had been exposed to warfare vesicant agents due to the appearance of blisters on the skin reminiscent of those produced by such agents. Eventually, and after a few weeks, the US Navy preventive medicine service arrived at the conclusion that the skin lesions were due to a toxin produced by beetles in the area in which the unit had been deployed[93].

In the sarin gas attacks in Japan the most common and evident clinical sign was the presence of miosis[11,97-110], which could be useful to enable fast and simple differentiation of a real intoxication by neurotoxic agents from a false one, and also prove useful in the differential diagnosis between intoxications by neurotoxic agents and cyanide agents[111]. In the event of contact with a neurotoxic agent in liquid form the presence of fasciculation and diaphoresis in the contact area can be useful in differential diagnosis. In this case the presence of miosis is not an early sign, but is instead due to the dermal absorption of the agent leading to systemic effects. In fact, miosis may not even be evident or may take up to 3 hours to appear, as in the only case described of the four attacks with VX carried out by Aum Shinrikyo in Japan[112,113]. The onset of convulsions indicates that the absorption of the agent via the respiratory or dermal system has already taken place and is affecting the central nervous system. The experience of the Iranian physicians with victims of neurotoxic agents during the Iran-Iraq war shows that during the first few moments it is sometimes difficult to distinguish between intoxication by neurotoxic agents from one by cyanide agents, particularly if no miosis or increase in secretions is observed. It has often happened that, mistakenly cyanide antidotal treatment has been given for neurotoxics, and vice versa[14]. For this reason, some military medical units have portable field devices to determine the level of cholinesterase in blood, so as to help the medical personnel in making the differential diagnosis. Among the victims treated for sarin gas intoxication at St. Luke's Hospital, it was noted that the reduction in plasma cholinesterase levels was normally correlated with the seriousness of the signs observed[100,105]. In the case of vesicant agents, specifically sulphur and nitrogen mustards, one of the main problems in differential diagnosis is the existence of a latency period of 2-48 hours, until the appearance of the first clinical symptoms and signs[114]. The Brund-Lowdy formula or the rule of the nines are not very useful in this type of intoxication. During the Iran-Iraq war it was observed that special population groups, especially children, were more susceptible to warfare neurotoxic agents and mustards[115,116].

The characteristic smell of some agents is usually mentioned as an organoleptic property which may be useful in identification, but the Iranian experience during the Iran-Iraq war reports that such properties are highly subjective, that they depend on the purity of the agent and that, in short, are not very useful when making a differential diagnosis[114].

Triage or casualty classification allows prioritization of attention, decontamination and evaluation of victims based on available resources. Triage is a dynamic process and should be performed at all levels, both in the hospital and extra-hospital environments[117,118]. Its correct application leads to a more efficient response by the medical intervention, as was the case in 11M[119]. The experience of the Japan attacks and that of the Iran-Iraq war shows that the classical triage systems when faced with multiple casualties of chemical weapons described in the military manuals seems complicated and impractical[120], especially if identification of a toxic syndrome through differential diagnosis should prove impossible; it is therefore necessary to complement such processes with simpler systems. For instance, classical triage of casualties of vesicant agents is based on the percentage of affected body surface[120]; however, in the case of mustards there is a latency period of 2-48 hours, so how is classification to be carried out if the affected body surface cannot be determined? The experience of the Iranian physicians with mustard gas has indeed indicated that it was practically impossible until the latency period had lapsed and that , even then, the first lesions appearing on the skin were not representative of the final seriousness of the intoxication[114].

A triage method in the event of mass casualties by chemical agents should be easy to memorize, fast to apply, reproducible and reliable. Based on such criteria, Cone and Koenig[121] propose a triage model for chemical weapon agent casualties

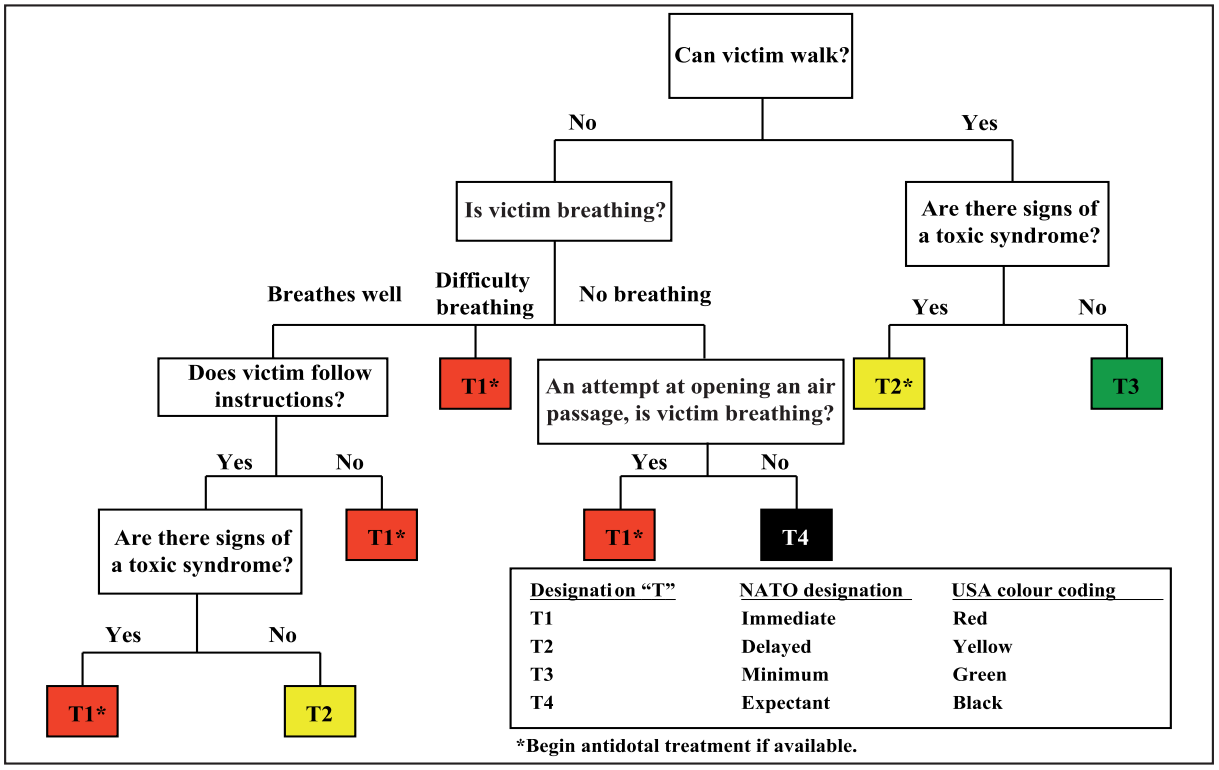


**Figure 4. Proposed triage algorithm for chemical agent casualties according to Cone and Koenig[121].**

based on the START method (Simple Triage and Rapid Treatment[122,123], but with three modifications to the algorithm: a subjective assessment of victims' breathing is performed, radial pulse assessment is eliminated and possible identification of a toxic syndrome by means of differential diagnosis is included (Figure 4).

## REFERENCES

**1-** Tu AT. Overview of sarin terrorist incidents in Japan in 1994 and 1995. En: Proceedings of the Sixth International Symposium on Protection Against Chemical and Biological Warfare Agents; 1998 May 10-15; Stockholm, Sweden; 1998. p. 13-8.

**2-** Tsuchihashi H, Katagi M, Tatsuno M, Miki A, Nishikawa M. Identification of VX metabolites and proof of VX use in the victim´s serum. International Symposium on NBC Terrorism Defense in Commemoration of the 10th Anniversary of the Tokyo Subway Attack; 2005 June 16-19; Chiba Institute of Science, Choshi City, Chiba, Japan.

**3-** Franse M, Westbroek H, Hielkema W, Jahromi S, Bonn D, Stunnenberg F. Chemical weapons: chaos and misunderstanding. En: Heyndrickx B, editor. Proceedings of the Second World Congress on New Compounds in Biological and Chemical Warfare: Toxicological Evaluation, Industrial Chemical Disasters, Civil Protection and Treatment; 1986 August 24-27; Ghent, Belgium. Ghent: University of Ghent; 1986. p. 631-5.

**4-** Moore D. Low-level nerve agent exposure: objectives of future research for military and civilian populations. En: Monov A, Dishovsky C, editores. Medical aspects of chemical and biological terrorism: chemical terrorism and traumatism. Sofia: Publishing House of the Union of Scientists in Bulgaria; 2005. p. 121-7.

**5-** Nogué S, Dueñas A, Nigorra M, García S. Disponibilidad de antídotos en caso de accidentes o atentados con armas químicas. Med Clin (Barc) 2002;118:650-2.

**6-** Miró O, Trejo O, Queralt C, Sánchez M. Preparación de los servicios de urgencias ante un eventual ataque terrorista con armas de destrucción masiva. Med Clin (Barc) 2003;121:596-7.

**7-** Olson D, Leitheiser A, Atchison C, Larson S, Homzik C. Public health and terrorism preparedness: cross-border issues. Public Health Rep 2005; 120(Suppl 1):76-83.

**8-** San Jaime A, Aguilar F, Miguel F, Sirgado L, López JC, Parra P. Gestión de la Central de Comunicaciones SAMUR-PC ante situaciones extraordinarias. Puesta al Día en Urgencias, Emergencias y Catástrofes 2005;6:109-17.

**9-** Schwenk M, Kluge S, Jaroni H. Toxicological aspects of preparedness and aftercare for chemical-incidents. Toxicology 2005;214:232-48.

**10-** Rodríguez P, Serra JA. Coordinación general de las actuaciones en el hospital. Med Clin (Barc) 2005;124(Suppl 1):3-7.

**11-** Okumura T, Suzuki K, Fukuda A, Kohama A, Takasu N, Ishimatsu S, et al. The Tokyo subway sarin attack: disaster management, part 2: hospital response. Acad Emerg Med 1998;5:618-24.

**12-** Okumura T, Suzuki K, Fukuda A, Kohama A, Takasu N, Ishimatsu S, et al. The Tokyo subway sarin attack: disaster management, part 1: community emergency response. Acad Emerg Med 1998;5:613-7.

**13-** Tokuda Y, Kikuchi M, Takahashi O, Stein GH. Prehospital management of sarin nerve gas terrorism in urban settings: 10 years of progress after the Tokyo subway sarin attack. Resuscitation 2006;68:193-202.

**14-** Newmark J. The birth of nerve agent warfare: lessons from Syed Abbas Foroutan. Neurology 2004;62:1590-6.

**15-** Carli P, Telion C, Baker D. Terrorism in France. Prehospital Disaster Med 2003;18:92-9.

**16-** Dechy N, Bourdeaux T, Ayrault N, Kordek MA, Le Coze JC. First lessons of the Toulouse ammonium nitrate disaster, 21st September 2001, AZF plant, France. J Hazard Mater 2004;111:131-8.
**17-** Gargallo MT, Muiño A, Ortiz FJ. Departamento de urgencias médico-quirúrgicas. Med Clin (Barc) 2005;124(Suppl 1):8-12.
**18-** Peral J, Turégano F, Pérez D, Sanz M, Martín C, Guerrero JE. Casualties treated at the closest hospital in the Madrid, March 11, terrorist bombings. Crit Care Med 2005;33(Suppl 1):S107-12.
**19-** Rendin RW, Welch NM, Kaplowitz LG. Leveraging bioterrorism preparedness for nonbioterrorism events: a public health example. Biosecur Bioterror 2005;3:309-15.
**20-** Cragin CL. The role of the Department of Defense in domestic weapons of mass destruction consequence management. Mil Med 2001;166(Suppl 2):1-3.
**21-** Socher MM, Leap ED. Exercises and educational courses in terrorism preparedness. En: Burstein JL, Schwartz RB, Swienton RE, editores. Medical response to terrorism: preparedness and clinical practice. Philadelphia: Lippincott Williams & Wilkins; 2005. p. 329-41.
**22-** Okumura T, Ninomiya N, Ohta M. The chemical disaster response system in Japan. Prehospital Disaster Med 2003;18:189-92.
**23-** Agency for Toxic Substances and Disease Registry (ATSDR). Managing hazardous materials incidents. Vol. I. Emergency medical services: a planning guide for the management of contaminated patients. Atlanta (GA): U.S. Department of Health and Human Services; 2000.
**24-** National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), U.S. Coast Guard (USCG), U.S. Environmental Protection Agency (EPA). Occupational safety and health guidance manual for hazardous waste site activities. Washington, D.C.: U.S. Department of Health and Human Services; 1985.
**25-** Ramón MF, Ballesteros S, Martínez-Arrieta R, Cabrera J. Armas químicas-Q-NBQ-Toxicidad y tratamiento. Madrid: Servicio de Información Toxicológica; 2003.
**26-** National Fire Protection Association (NFPA). NFPA 1994: Standard on protective ensembles for chemical/biological terrorism incidents. 2001 edition. Quincy (MA): NFPA; 2001.
**27-** UNE-EN 14387:2004/AC (junio 2005). Equipos de protección respiratoria. Filtros contra gases y filtros combinados. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2005.
**28-** UNE-EN 14387 (julio 2004). Equipos de protección respiratoria. Filtros contra gases y filtros combinados. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2004.
**29-** UNE-EN 12942 (mayo 1999). Equipos de protección respiratoria. Equipos filtrantes de ventilación asistida provistos de máscaras o mascarillas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1999.
**30-** UNE-EN 12942/A1 (abril 2003). Equipos de protección respiratoria. Equipos filtrantes de ventilación asistida provistos de máscaras o mascarillas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2003.
**31-** De la Iglesia A, Gómez J, Ledesma MJ, Ledesma J, Pacheco L, Sáenz R, et al. La vigilancia de la salud en usuarios de equipos de protección individual respiratoria (1ª parte). Prevención, Trabajo y Salud 2002;(22):4-12.
**32-** UNE-EN 1822-1 (mayo 1999). Filtros absolutos (HEPA y ULPA). Parte 1: Clasificación, principios generales del ensayo, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1999.
**33-** UNE-EN 1822-2 (mayo 1999). Filtros absolutos (HEPA y ULPA). Parte 2: Producción de aerosol, aparatos de medición, estadísticas de contaje de partículas. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1999.
**34-** UNE-EN 1822-3 (mayo 1999). Filtros absolutos (HEPA y ULPA). Parte 3: Ensayo de medio filtrante plano. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1999.
**35-** UNE-EN 1822-4 (septiembre 2001). Filtros absolutos (HEPA y ULPA). Parte 4: Ensayo de estanquidad de la célula filtrante (método de exploración). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2001.
**36-** UNE-EN 1822-5 (junio 2001). Filtros absolutos (HEPA y ULPA). Parte 5: Medida de la eficacia de la célula filtrante. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2001.
**37-** UNE-EN 13274-7 (septiembre 2003). Equipos de protección respiratoria. Métodos de ensayo. Parte 7: determinación de la penetración de filtros de partículas. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2003.
**38-** UNE-EN 143/AC (diciembre 2002). Equipos de protección respiratoria. Filtros contra partículas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2002.
**39-** UNE-EN 143 (junio 2001). Equipos de protección respiratoria. Filtros contra partículas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2001.
**40-** UNE-EN ISO 943-1 (abril 2003). Ropa de protección contra productos químicos, líquidos y gaseosos, incluyendo aerosoles líquidos y partículas sólidas. Parte 1: Requisitos de prestaciones de los trajes de protección química, ventilados y no ventilados, herméticos a gases (Tipo 1) y no herméticos a gases (Tipo 2). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2003.
**41-** UNE-EN 14605 (noviembre 2005). Ropas de protección contra productos químicos líquidos. Requisitos de prestaciones para la ropa con uniones herméticas a los líquidos (Tipo 3) o con uniones herméticas a las pulverizaciones (Tipo 4), incluyendo las prendas que ofrecen protección únicamente a ciertas partes del cuerpo (Tipos PB [3] y PB [4]). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2005.
**42-** UNE-EN 13982-1 (mayo 2005). Ropa de protección para uso contra partículas sólidas. Parte 1: Requisitos de prestaciones para la ropa de protección química que ofrece protección al cuerpo completo contra partículas sólidas suspendidas en el aire (ropa de tipo 5). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2005.
**43-** UNE-EN 13034 (noviembre 2005). Ropa de protección contra productos químicos líquidos. Requisitos de prestaciones para la ropa de protección química que ofrece protección limitada contra productos químicos líquidos (equipos del tipo 6 y de tipo PB [6]). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2005.
**44-** UNE-EN 14325 (septiembre 2004). Ropa de protección contra productos químicos. Métodos de ensayo y clasificación de las prestaciones de los materiales, costuras, uniones y ensamblajes de la ropa de protección contra productos químicos. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2004.
**45-** UNE-EN 943-2 (septiembre 2002). Ropa de protección contra productos químicos, líquidos y gaseosos, incluyendo aerosoles líquidos y partículas sólidas. Parte 2: Requisitos de prestaciones de los trajes de protección química, herméticos a gases (Tipo 1), destinados a equipos de emergencia (ET). Madrid: Asociación Española de Normalización y Certificación (AENOR); 2002.
**46-** UNE-EN ISO 6529 (mayo 2002). Ropas de protección. Protección contra productos químicos. Determinación de la resistencia de los materiales de las ropas de protección a la permeación de líquidos y gases. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2002.
**47-** UNE-EN ISO 6530 (junio 2005). Ropa de protección. Protección contra productos químicos líquidos. Método de ensayo para la resistencia de los materiales a la penetración por líquidos. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2005.
**48-** Brouwer DH, Marquart H, Van Hemmen JJ. Proposal for an approach with default values for the protection offered by PPE, under European new or existing substance regulations. Ann Occup Hyg 2001;45:543-53.
**49-** Perkins JL, Rainey KC. The effect of glove flexure on permeation parameters. Appl Occup Environ Hyg 1997;12:206-10.
**50-** Raheel M. Pesticide transmission in fabrics: effect of perspiration. Bull Environ Contam Toxicol 1991;46:837-44.
**51-** Yang Y, Li S. Frictional transition of pesticides from protective clothing. Arch Environ Contam Toxicol 1993;25:279-84.
**52-** UNE-EN 374-3 (abril 2004). Guantes de protección contra los productos químicos y los microorganismos. Parte 3: determinación de la resistencia a la permeación por productos químicos. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2004.
**53-** Evans PG, McAlinden JJ, Griffin P. Personal protective equipment and dermal exposure. Appl Occup Environ Hyg 2001;16:334-7.
**54-** Blayney MB. The need for empirically derived permeation data for personal protective equipment: the death of Dr. Karen E. Wetterhahn. Appl Occup Environ Hyg 2001;16:233-6.
**55-** Occupational Safety and Health Administration (OSHA). OSHA best practices for hospital-based first receivers of victims from mass casualty in-

cidents involving the release of hazardous substances. Washington, D.C.: OSHA; 2005.
**56-** U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). Technical Guide 275: Personal protective equipment guide for military medical treatment facility personnel handling casualties from weapons of mass destruction and terrorism events. Aberdeen Proving Ground (MD); USACHPPM; 2003.
**57-** Arad M, Epstein Y, Krasner E, Danon YL, Atsmon J. Principles of respiratory protection. En: Danon YL, Shemer J, editores. Chemical warfare medicine: aspects and perspectives from the Persian Gulf War. Jerusalem: Gefen Publishing House Ltd.; 1994. p. 65-74.
**58-** Golan E, Arad M, Atsmon J, Shemer J, Nehama H. Medical limitations of gas mask for civilian populations: the 1991 experience. Mil Med 1992; 157:444-6.
**59-** Harber P, Shimozaki S, Barrett T, Losides P, Fine G. Effects of respirator dead space, inspiratory resistance, and expiratory resistance ventilatory loads. Am J Ind Med 1989;16:189-98.
**60-** Harber P, SooHoo K, Lew M. Effects of industrial respirators on respiratory timing and psychophysiologic load sensitivity. J Occup Environ Med 1988;30:256-62.
**61-** Johnson AT, Scott WH, Lausted CG, Benjamin MB, Coyne KM, Sahota MS, et al. Effect of respirator inspiratory resistance level on constant load treadmill work performance. Am Ind Hyg Assoc J 1999;60:474-9.
**62-** Johnson RF, Kobrick JL. Psychological aspects of military performance in hot environments. En: Lounsbury DE, Bellamy RF, Zajtchuk R, Pandolf KB, Burr RE, Wenger CB, editores. Textbook of military medicine – Medical aspects of harsh environments. Volume 1. Section 1: Hot environments. Washington, D.C.: Office of The Surgeon General, Department of the Army; 2002. p. 135-59.
**63-** Krueger GP. Psychological and performance effects of chemical-biological protective clothing and equipment. Mil Med 2001;166(Suppl 2):41-3.
**64-** Louhevaara V. Physiological effects associated with the use of respiratory protective devices: a review. Scand J Work Environ Health 1984;10: 275-81.
**65-** Raven PB, Dodson AT, Davis TO. The physiological consequences of wearing industrial respirators: a review. Am Ind Hyg Assoc J 1979;40:517-34.
**66-** Ritchie EC. Psychological problems associated with mission-oriented protective gear. Mil Med 2001;166(Suppl 2):83-4.
**67-** Ritchie EC. Psychological problems associated with wearing mission-oriented protective posture gear. En: Zajtchuk R, Bellamy RF, editores. Textbook of military medicine – warfare, weaponry and the casualty (part 1): medical aspects of chemical and biological warfare. Washington, D.C.: Office of The Surgeon General, Department of the Army; 1997. p. 393-6.
**68-** Ritchie EC. Treatment of gas mask phobia. Mil Med 1992;157:104-6.
**69-** Schier JG, Hoffman RS. Personal protective equipment. En: Burstein JL, Schwartz RB, Swienton RE, editores. Medical response to terrorism: preparedness and clinical practice. Philadelphia: Lippincott Williams & Wilkins; 2005. p. 284-9.
**70-** UNE-EN 136/AC (octubre 2004). Equipos de protección respiratoria. Máscaras completas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 2004.
**71-** UNE-EN 136 (julio 1998). Equipos de protección respiratoria. Máscaras completas. Requisitos, ensayos, marcado. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1998.
**72-** Yellin A, Eilon S, Simansky DA, Shiner R, Epstein Y, Lieberman Y. Pneumothorax and the nuclear, biological, and chemical protective mask. En: Danon YL, Shemer J, editores. Chemical warfare medicine: aspects and perspectives from the Persian Gulf War. Jerusalem: Gefen Publishing House Ltd.; 1994. p. 109-12.
**73-** Cadarette BS, Cheuvront SN, Kolka MA, Stephenson LA, Montain SJ, Sawka MN. Intermittent microclimate cooling during exercise-heat stress in US army chemical protective clothing. Ergonomics 2006;49:209-19.
**74-** Cadarette BS, Levine L, Staab JE, Kolka MA, Correa MM, Whipple M, et al. Upper body cooling during exercise-heat stress wearing the improved toxicological agent protective system for HAZMAT operations. AIHA J 2003;64:510-5.
**75-** Kobrick JL, Johnson RF, McMenemy DJ. Subjective reactions to atropine/2-PAM chloride and heat while in battle dress uniform and in chemical protective clothing. Mil Psychol 1990;2:95-111.
**76-** Goldman RF. Introduction to heat-related problems in military operations. En: Lounsbury DE, Bellamy RF, Zajtchuk R, Pandolf KB, Burr RE, Wenger CB, editores. Textbook of military medicine – Medical aspects of harsh environments. Volume 1. Section 1: Hot environments. Washington, D.C.: Office of The Surgeon General, Department of the Army; 2002. p. 3-49.
**77-** Parsons KC. International standards for the assessment of the risk of thermal strain on clothed workers in hot environments. Ann Occup Hyg 1999;43:297-308.
**78-** Piñeiro N, Martínez JL, Alemparte E, Rodríguez JC. Golpe de calor. Emergencias 2004;16:116-25.
**79-** Mudambo SM, Reynolds N. Body fluid shifts in soldiers after a jogging/walking exercise in the heat: effects of water and electrolyte solution on rehydration. Cent Afr J Med 2001;47:220-5.
**80-** Flaishon R, Sotman A, Ben-Abraham R, Rudick V, Varssano D, Weibroum AA. Antichemical protective gear prolongs time to successful airway management: a randomized crossover study in humans. Anesthesiology 2004;100:260-6.
**81-** Garner A, Laurence H, Lee A. Practicality of performing medical procedures in chemical protective ensembles. Emerg Med Australas 2004;16: 108-13.
**82-** Hendler I, Nahtomi O, Segal E, Perel A, Wiener M, Meyerovitch J. The effect of full protective gear on intubation performance by hospital medical personnel. Mil Med 2000;165:272-4.
**83-** Kadivar H, Adams SC. Treatment of chemical and biological warfare injuries: insights derived from the 1984 Iraqi attack on Majnoon Island. Mil Med 1991;4:171-7.
**84-** Comité Técnico 79 del Comité Europeo de Normalización (CEN/TC 79). Informe CR 529:1993. Recomendaciones para la selección y uso de equipos de protección respiratoria. Versión en español elaborada por el comité técnico AEN/CTN 81. Madrid: Asociación Española de Normalización y Certificación (AENOR); 1998.
**85-** De la Iglesia A, Gómez J, Ledesma MJ, Ledesma J, Pacheco L, Sáenz R, et al. La vigilancia de la salud en usuarios de equipos de protección individual respiratoria (2ª parte). Prevención, Trabajo y Salud 2003;(23):16-28.
**86-** Martyny J, Glazer CS, Newman LS. Respiratory protection. N Engl J Med 2002;347:824-30.
**87-** Van der Jagt K, Tielemans E, Links I, Brouwer D, van Hemmen J. Effectiveness of personal protective equipment: relevance of dermal and inhalation exposure to chlorpyrifos among pest control operators. J Occup Environ Hyg 2004;1:355-62.
**88-** Coffey CC, Campbell DL, Myers WR, Zhuang Z, Sam S. Comparison of six respirator fit-test methods with an actual measurement of exposure in a simulated health care environment. Part II. Method comparison testing. Am Ind Hyg Assoc J 1998;59:862-70.
**89-** Mullins HE, Danisch SG, Johnston AR. Development of new qualitative test for fit testing respirators. Am Ind Hyg Assoc J 1995;56:1068-73.
**90-** Garrod ANI, Rajan-Sithamparanadarajah R. Developing COSHH essentials: dermal exposure, personal protective equipment and first aid. Ann Occup Hyg 2003;47:577-88.
**91-** Murray GM, Lawrence DS. Hazardous environment monitoring. En: Mesilaakso M, editor. Chemical weapons convention chemicals analysis: sample collection, preparation, and analytical methods. West Sussex: John Wiley & Sons Ltd; 2005. p. 65-88.
**92-** Domingo J, Pita R. To be or not to be: the need to be sure in chemical detection. NBC International. En prensa 2006.
**93-** Claborn DM. Environmental mimics of chemical warfare agents. Mil Med 2004;12:958-61.
**94-** Willems JL. Clinical management of mustard gas casualties. Ann Med Mil Belg 1989;3(Suppl 1):1-61.
**95-** Somani SM. Toxicokinetics and toxicodynamics of mustard. En: Somani SM, editor. Chemical warfare agents. San Diego (CA): Academic Press, Inc.; 1992. p. 13-50.
**96-** Pita R, Anadón A, Martínez-Larrañaga MR. Neurotoxinas con actividad anticolinesterásica y su posible uso como agentes de guerra. Med Clin (Barc) 2003;121:511-7.
**97-** Kato T, Hamanaka T. Ocular signs and symptoms caused by exposure to sarin gas. Am J Ophthalmol 1996;121:209-10.
**98-** Masuda N, Takatsu M, Morinari H, Ozawa T. Sarin poisoning in Tokyo subway. Lancet 1995;345:1446.
**99-** Morita H, Yanagisawa N, Nakajima T, Shimizu M, Hirabayashi H, Oku-

dera H, et al. Sarin poisoning in Matsumoto, Japan. Lancet 1995;346:290-3.

**100-** Nozaki H, Hori S, Shinozawa Y, Fujishima S, Takuma K, Kimura H, et al. Relationship between pupil size and acetylcholinesterase activity in patients exposed to sarin vapor. Intensive Care Med 1997;23:1005-7.

**101-** Nozaki H, Hori S, Shinozawa Y, Fujishima S, Takuma K, Sagoh M, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. Intensive Care Med 1995;21:1032-5.

**102-** Ohbu S, Yamashina A, Takasu N, Yamaguchi T, Murai T, Nakano K, et al. Sarin poisoning on Tokyo subway. South Med J 1997;90:587-93.

**103-** Okudera H. Clinical features on nerve gas terrorism in Matsumoto. J Clin Neurosci 2002;9:17-21.

**104-** Okudera H, Morita H, Iwashita T, Shibata T, Otagiri T, Kobayashi S, et al. Unexpected nerve gas exposure in the city of Matsumoto: report of rescue activity in the first sarin gas terrorism. Am J Emerg Med 1997;15: 527-8.

**105-** Okumura T, Hisaoka T, Naito T, Isonuma H, Okumura S, Miura K, et al. Acute and chronic effects of sarin exposure from the Tokyo subway incident. Environ Toxicol Pharmacol 2005;19:447-50.

**106-** Okumura T, Takasu N, Ishimatsu S, Miyanoki S, Mitsuhashi A, Kumada K, et al. Report on 640 victims of the Tokyo subway sarin attack. Ann Emerg Med 1996;28:129-35.

**107-** Suzuki J, Kohno T, Tsukagosi M, Furuhata T, Yamazaki K. Eighteen cases exposed to sarin in Matsumoto, Japan. Intern Med 1997;36:466-70.

**108-** Suzuki T, Morita H, Ono K, Maekawa K, Nagai R, Yazaki Y. Sarin poisoning in Tokyo subway. Lancet 1995;345:980.

**109-** Yokoyama K, Yamada A, Mimura N. Clinical profiles of patients with sarin poisoning after the Tokyo subway attack. Am J Med 1996;100:586.

**110-** Yokoyama K, Ogura Y, Kishimoto M, Hinoshita F, Hara S, Yamada A, et al. Blood purification for severe sarin poisoning after the Tokyo subway attack. JAMA 1995;274:379.

**111-** World MJ. Toxic gas trauma. Lancet 1995;346:260-1.

**112-** Kaplan DE. Aum Shinrikyo (1995). En: Tucker JB, editor. Toxic terror: assessing terrorist use of chemical and biological weapons. Cambridge (MA): Belfer Center for Science and International Affairs; 2000. p. 207-26.

**113.-** Nozaki H, Aikawa N, Fujishima S, Suzuki M, Shinozawa Y, Hori S, et al. A case of VX poisoning and the difference from sarin. Lancet 1995; 346:698-9.

**114-** Pita R. Armas químicas: agentes vesicantes de guerra. En: Ministerio de Justicia, editor. Curso de armas químicas y biológicas. Madrid: Centro de Estudios Jurídicos. En prensa 2006.

**115-** Balali-Mood M, Balali-Mood K. Nerve agents. En: Brent J, Wallace K, Burkhart KK, Phillips S, Donovan JW, editores. Critical care toxicology: diagnosis and management of the critically poisoned patient. Pennsylvania: Elsevier Mosby; 2005. p. 1379-93.

**116-** Khateri S, Ghanei M, Soroush MR, Haines D. Effects of mustard gas exposure in pediatric patients: long-term health status of mustard-exposed children, 14 years after chemical bombardment of Sardasht. The Journal of Burns and Wounds [revista electrónica] 2003;2. Disponible en http://journalofburnsandwounds.com (consultado el 19-02-06).

**117-** Gómez J. Clasificación de pacientes en los servicios de urgencias y emergencias: hacia un modelo de triaje estructurado de urgencias y emergencias. Emergencias 2003;15:165-74.

**118-** Peláez MN, Alonso J, Gil FJ, Larrea A, Buzón C, Castelo I. Método SHORT. Primer triaje extrahospitalario ante múltiples víctimas. Emergencias 2005;17:169-75.

**119-** Ortega IM. "Triage" en los atentados del 11-M. Análisis ético y legal. REMI [revista electrónica] 2004;4. Disponible en http://remi.uninet.edu (consultado el 13 de abril de 2005).

**120-** Sidell FR. Triage of chemical casualties. En: Zajtchuk R, Bellamy RF, editores. Textbook of military medicine – warfare, weaponry and the casualty (part 1): medical aspects of chemical and biological warfare. Washington, D.C.: Office of The Surgeon General, Department of the Army; 1997. p. 197-228.

**121-** Cone DC, Koenig KL. Mass casualty triage in the chemical, biological, radiological, or nuclear environment. Eur J Emerg Med 2005;12:287-302.

**122-** Cone DC, MacMillan DS. Mass-casualty triage systems: a hint of science. Acad Emerg Med 2005;12:739-41.

**123-** Garner A, Lee A, Harrison K, Schultz CH. Comparative analysis of multiple-casualty incident triage algorithms. Ann Emerg Med 2001;38:541-8.