INTRODUCTION

Definition

The NATO definition of a chemical agent is:

A chemical substance which is intended for use in military operations to kill, seriously injure or incapacitate people because of its physiological effects.

Excluded from this definition are riot control agents (sensory incapacitants), herbicides, smokes and flame. Brief consideration will, however, be given to riot control agents, herbicides, smoke and flame materials, and toxic industrial/agricultural chemicals in this special issue of the Journal.

New agents are being developed by certain nations and some chemical agents may be used together as a mixture. By constant vigilance on the part of all medical personnel in looking for new or unexpected syndromes, and by prompt reporting of any suspicious event, the use of new or mixed agents can be determined.

This special issue serves as a guide and reference for members of the Defence Medical Services on the recognition and management of chemical weapon (CW) casualties and injuries from other noxious chemicals. It also provides information on procedures for recognising chemical casualties, and procedures for medical treatment including decontamination.

Historical

Chemical weapons in the modern sense were first used in World War I, when chlorine gas was released into a favourable wind from large cylinders. This surprise operation caused many casualties, demoralisation of the forces attacked and demonstrated the need for protection from this kind of warfare. The first improvised mask was a cotton pad soaked in sodium thiosulphate, glycerine and sodium carbonate, but more effective respiratory protection evolved (Figure 1). Subsequently in World War I, a great variety of chemical agents was used by both sides, the most damaging being the blister-producing "mustard gas"; this agent also had notable ocular effects (Figure 2).

Military clothing, even with a respirator, gave little protection against this agent. Chemical agents were not used in World War II, but at the end of the war, stockpiles of newer agents called "nerve gases," were discovered. These were found to be effective at much lower concentrations than those agents known up to that time. The standard of training and preparedness of the Allies and the fear of retaliation were possible reasons why chemical agents were not used by the enemy.

Between World Wars I and II, mustard gas was used with considerable effect against unprotected troops (for example, by the Italians in Abyssinia [1936], and the Japanese in Manchuria [1937-41]). Since World War II, there have been several confirmed reports that chemical agents have been used in armed conflicts, including the Iran-Iraq conflict.

Riot control agents such as CS ("tear gas") have been used repeatedly, for example, in South-East Asia to support tactical operations - in particular, to flush out guerrillas from hiding and to render places of concealment untenable. These compounds – classed as sensory irritants - are frequently used internationally as riot control agents by

Fig 1. Respiratory protection – British soldiers in WW1 wearing the Phenate Hexamine Helmet.

Fig 2. British soldiers in WW1 temporarily blinded by sulphur mustard vapour – Advanced Dressing Station near Bethune, France, 10 April 1918.

Fig 3. Consequences of the release of Sarin (GB) on the Tokyo underground in 1995.

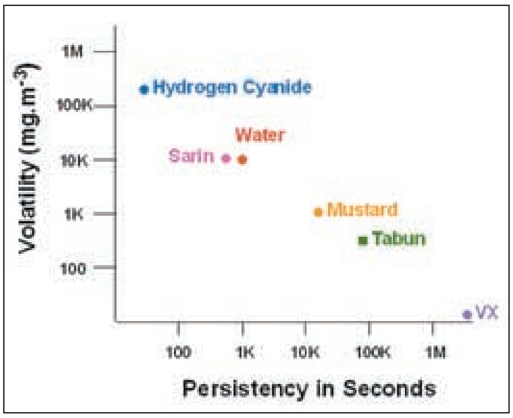

Fig 4. Persistency of agents with water as a reference.

police forces.

The effectiveness of chemical agents as tactical weapons was clearly demonstrated in World War I and in the Iran-Iraq conflict. They can affect both forward and rear areas. In addition, CW agents could be used against military or civilian targets in terrorist actions, as realised in the Tokyo subway incident of 1995 when the nerve agent Sarin was released (Figure 3).

In 1997 the Chemical Weapons Convention (CWC) came into effect. This convention prohibits the development, stock-piling and use of CW agents. Despite this convention, the use of CW against NATO forces cannot be ruled out.

General Factors Influencing the Employment and Choice of Chemical Agents

The effective use of any chemical agent is dependent on its physical and chemical properties and on meteorological conditions at the time of and after release. *Persistency* is defined as the length of time that an agent will present an inhalation or contact hazard (Figure 4). It is a function of the properties of the agent, meteorological conditions and the physical and chemical properties of the surface upon which the agent has deposited. Chemical agents may be divided into two main categories: non-persistent and persistent agents.

- *Non-persistent agents* disperse rapidly after release and present an immediate, short duration hazard. They are released as airborne particles, liquids and gases, and intoxication usually results from inhalation.
- *Persistent agents* continue to present a hazard for considerable periods after delivery by remaining as contact hazard or by vaporising over a period to produce a hazard by inhalation. Non-persistent agents may be made persistent by thickening.

The meteorological factors which will influence the duration of persistence of chemical agents are:

- *Winds*. The effect of wind is to disperse agents rapidly in open country. However, dangerous concentrations may remain longer in woods, field defences, dug-outs and built-up areas.
- *Temperature*. High temperatures decrease the persistency of agents and cause higher vapour concentrations. Low temperatures increase the persistency of agents. Some agents may freeze thus reducing the immediate contact hazard. There is a danger of carrying such frozen agents on clothing and equipment into a warm building with the subsequent risk of release of toxic vapour.
- *Rain*. Rain disposes, dilutes and promotes hydrolysis of agents. This reduces their effectiveness but does not make them necessarily ineffective under these conditions.
- *Atmospheric Stability*. When the air temperature is higher than that at ground level (a state of "inversion"), agents in the vapour state will persist for longer periods than when the air temperature is lower than that at ground level (a state of "lapse").

Effectiveness is the capacity of an agent to produce the maximum number of casualties or amount of disruption of operations with the least amount of agent, although other tactical criteria may be used to gauge this effectiveness. "Effectiveness" is a general term which takes in such criteria as suitability, toxicity, irritancy, etc. For instance, for two similar volatile toxic agents, the one which is toxic at a lower dose can be said to be more effective. Similarly, for two irritant compounds, the one which is irritant at a lower dose can be said to be the more effective. Effectiveness is also dependent on the ability of the population attacked to neutralise or counter the effects of agents once they have been delivered. The duration of effectiveness depends on the physical characteristics of the agent, the amount of agent delivered, the weapon system used and the terrain and weather in the target area at the time the agent is delivered, and subsequently.

Characteristics

Physical

Under ambient conditions, the physical state of agents may be gaseous, liquid or solid. Their vapour pressures vary from high to negligible. Their vapour densities vary from slightly lighter to considerably heavier than air. The range of odours varies from none to highly pungent or characteristic. They may be soluble or insoluble in water. From these characteristics, the behaviour of the agents in the field with regard to vapour hazard, persistency and possible means of decontamination, etc. may be determined. Agents with a low boiling point and high vapour pressure tend to be non-persistent.

Chemical

The only general characteristic of the known agents is that they are sufficiently stable to survive dissemination and transport to the site of their biological action. Their inherent reactivity and stability can vary widely. Some chemically reactive agents denature rapidly, whereas other less reactive agents require, for example, bleach solutions or other reactive skin decontaminants to inactivate them. Solid adsorbents (e.g. fullers' earth) can be used as decontaminants but they do not denature agents and the potential for off-gassing should be recognised.

Toxicological

Not all individuals of a biological species react in the same way to a given amount of agent. Some are more or less sensitive as a result of many factors, of which gender, genetic background, race and age are examples. Also, toxicological studies estimate the biological effects of potential agents by different routes of exposure. The physical properties of such materials may affect the toxicological studies since the response of the biological system concerned may vary depending on the physical state of the material. Studies of the mode of action are important for the development of medical countermeasures and physical protection.

Terminology

Dose. The dose is the quantity of the compound received by the subject.

LD50. The LD (lethal dose) 50 is the dose which kills 50% of the exposed population.

ID50. The ID (incapacitating dose) 50 is the dose which incapacitates 50% of the exposed population.

Ct (Concentration time). The Ct is a measure of exposure to a vapour or aerosol. The concentration in the air and the time of exposure govern the dose received; the rate of respiration is also an important factor. A basic assumption is that when the product of concentration and time is constant, the biological effect is also constant (over a limited range of concentration and time). For very short or long exposures, the biological effect may vary. Concentration is normally expressed as $mg.m^{-3}$ and time as minutes (min), so that the concentration time (Ct) is expressed as $mg.min.m^{-3}$.

LCt50. The LCt (lethal concentration time) 50 is the Ct which will kill 50% of the exposed population.

ICt50. The ICt (incapacitating concentration time) 50 is the Ct which will incapacitate 50% of the exposed population.

Routes of Absorption

Chemical agents may enter the body by several routes and the nature, onset and duration of signs and symptoms may vary accordingly. Gases, vapours and aerosols may be absorbed through any part of the respiratory tract, from the mucosa of the nose and mouth to the alveoli of the lungs. They may also be directly absorbed by the skin and eye. Aerosol particles larger than 5 μm tend to be retained in the upper respiratory tract, while those smaller than 1 μm tend to be breathed in and out again, with some of these smaller particles being retained. Droplets of liquid and, less commonly, solid particles may be absorbed through the surface of the skin and mucous membranes. Toxic compounds with a characteristic action on the skin can produce their effects when deposited on the skin as solid or liquid particles. Agents which penetrate the skin may form temporary reservoirs so that delayed absorption may occur. Even the vapour of some volatile agents can penetrate the intact skin and intoxication may follow. Wounds or abrasions (even minor injuries caused by shaving or by chemical depilation) present areas which are more permeable than intact skin. Chemical agents may contaminate food and drink and so be absorbed by the gastrointestinal tract. The penetration of agents by these various routes may not be accompanied by irritation or damage to the surfaces concerned.

Further Reading

Beswick FW, Maynard R. "Poisoning in Conflict," in Oxford Textbook of Medicine, Eds. Wetherall, DL, Ledingham JGG, and Warrell DA. Pub. Oxford University Press.