WAR WOUNDS AND AIR RAID CASUALTIES

The following article is a supplement to the series of lectures on war wounds and air raid casualties printed in these columns*

CHEMICAL WARFARE AND THE DOCTOR—I

BY

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From the earliest times in the history of the world certain sociological, physical, and biological factors have governed the problem of the growth of population. Disease, as seen in individual cases, in epidemics, or in pandemics sweeping Europe in the Middle Ages, has from time to time decimated the population. War, with its horrors and vast numbers of men killed by disease and wounds, may be included in this list, together with famine, pestilence, floods, and earthquakes.

The present war, however, will be different and probably more horrible. While in former days war was an affair where men fought men, and women and children suffered accidentally or indirectly, to-day the idea is accepted by some Governments that it is justifiable for one nation to attempt to impose its will on another by striking a sudden swift crushing blow on vital vulnerable points in the country of its enemies. That is to say, civil centres are to be attacked in addition to, or apart from, definite targets of naval or military importance. For this reason many conferences have been held under the auspices of the International Red Cross of Geneva since the year 1920. The problem of protecting the civil population has now been accepted by every Government in Europe, including that of Great Britain, whose A.R.P. organization is so well known to all.

The subject of the medical aspects of chemical warfare is of grave practical importance to all medical men. It is not enough to be told how to treat the results of exposure to certain gases. As in typhoid, for instance, a study of the aetiology, pathology, and clinical picture is essential. In the present paper a list of substances most likely to be met with in chemical warfare is given, together with an account of their physical and chemical properties and a description of their physiological action. Their pathological effects will be discussed in the next paper.

History of Chemical Warfare

A full account of the history of chemical warfare may be found in a book published in 1935 by two French naval surgeons, Héderer and Istin. "Gas" is one of the most ancient devices used in fighting. Details are described by Thucydides of the method employed in the Peloponnesian War in the fifth century B.C. After months of siege, faggots impregnated with pitch and sulphur were set on fire outside the city walls. The wind drove on the cloud and rendered one point of the defence untenable. However, a thunderstorm broke, the rain extinguished the fire, and the first gas attack on record was unsuccessful. In the same campaign an efficient "flame projector" was designed and used. In 1726 Fleming described in his book *The Perfect German Soldier* several new poisons to be incorporated in grenades.

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Chemical warfare fell into disuse for the next hundred years, and the British Government refused to sanction the use of toxic shells and grenades in the Crimea. In spite of the agreement of The Hague, 1899, chemical warfare was reintroduced in the Great War and enormously developed. Although occasional use of toxic shells by the Germans was reported from October, 1914, onwards, it was not until April 22, 1915, that chemical warfare was indulged in on a large scale. The Germans launched clouds of chlorine on a six-kilometre front in a surprise attack, causing 15,000 casualties, 5,000 of them fatal. In addition large numbers of prisoners and quantities of war material were lost to the enemy. The success of this attack depended on the element of surprise. No means were at hand to protect the troops. Major-General C. H. Foulkes, the officer in charge of the Special Brigade in France in the great war, writing in his book *Gas* in 1936, states that many warnings were received of this gas attack. These were not appreciated, however, until 1932. After the April, 1915, attack the matter was at once taken up by our Army Medical Service.

The first mask was immediately devised at the Royal Army Medical College, Millbank. This consisted of a pad of wool impregnated with sodium hyposulphite and tied over the mouth and nose by a length of veiling material. Large numbers of women workers were collected, and in three days the troops at the front were provided with 100,000 masks. In September of the same year chlorine was used by our troops at the beginning of the Battle of Loos. The attack was not very successful, and I remember seeing our own men admitted to a casualty clearing station later in the day with pink eyes and green buttons. Intensive work was carried out in the perfection of the anti-gas respirator, until finally an article was produced which was proof against all gases except carbon monoxide, and which permitted free action in fighting. In 1917 the Germans first used "mustard gas"—another surprise.

It is interesting to note that with the provision of respirators, introduction of gas discipline, and dissemination of a knowledge of chemical warfare, the casualties progressively diminished although the number of our troops in the field was enormously increased.

Agents used in Chemical Warfare

The most useful and generally accepted classification of war "gases" is the physiological one, determined by the action of these chemical substances in various parts of the body. The main groups are, in the order of their toxicity: (I) lacrimators (tear gas); (II) sternutators (nose irritants); (III) vesicants (blistering); (IV) lung irritants; (V) paralytics; (VI) gases met with accidentally, as carbon monoxide.

The following list is compiled from Vedder (1925, U.S.A.), with up-to-date additions.

I. Lacrimators.—Acrolein; benzyl bromide; bromoacetone; bromobenzyl cyanide (B.B.C.); chloro-acetophenone (C.A.P.); dibrom-methyl-ethyl-ketone; ethyl-iodoacetate (K.S.K.); methyl-chlorosulphonate; monobrom-methyl-ethyl-ketone; xylene bromide.

II. *Sternutators*.—Diphenylchlorarsine (D.A.)—Clark I; diphenylcyanarsine (D.C.)—Clark II; diphenylarsine-chlorarsine (D.M.)—Adamsite (or chloro-dihydro-phenarsazine); ethyl-dichlorarsine; *N*-ethyl-carbazol.

III. *Vesicants*.—Lewisite—chlorovinyl-dichlorarsine; mustard—dichlorodiethyl sulphide (thiodiglycol chloride).

IV. *Lung Irritants*.—Chlorine; chloromethyl-chloroformate (palite); chloropicrine; cyanogen bromide; dichloromethyl ether; phenyl-carbylamine chloride; phosgene; stannic chloride; trichloromethyl-chloroformate (diphosgene or superpalite).

V. *Paralysants*.—Hydrocyanic acid; sulphuretted hydrogen.

VI. Gases met with accidentally—see Group III below.

In the *Medical Manual of Chemical Warfare* (H.M. Stationery Office, 1939) the following classification is suggested, with a view to combining both tactical object and physiological effect.

Group I.—Lethal: (a) vesicants; (b) lung irritants; (c) paralysants.

Group II.—Harassing: (a) lacrimators; (b) sensory irritants.

Group III.—Accidental (gases not used as weapons, as carbon monoxide).

The physical and chemical properties of the chemical agents most likely to be met with are briefly described below. The volatility of these substances is important. Gases may be persistent or non-persistent (P. or N.P.).

Lacrimators

Bromobenzyl cyanide (B.B.C.) (discovered in 1881), as commercially prepared, is a heavy, oily, dark brown liquid, very persistent, so that contaminated earth causes lacrimation after thirty days' exposure. B.B.C. corrodes metals except lead; it is expensive, and not likely to be used.

Chloro-acetophenone (C.A.P.) (1887) consists of white crystals melting at about 60° C. and with a high boiling-point and a low vapour pressure. It is very slightly soluble in water, but soluble in ether, alcohol, or benzene, and a hot aqueous solution of sodium carbonate. It smells of cheap scented soap. It is cheap, and easy to manufacture and store in shells or bombs, so that it is the substance most likely to be met with. It is non-persistent. It may irritate and redden the skin.

Ethyl-iodoacetate (K.S.K.) is a dark brown liquid, invisible in the gaseous state. It is persistent, and has a pear-drop smell.

Sternutators (All Non-persistent)

These substances form the "irritant smokes" and contain arsenic.

Diphenylchlorarsine (D.A.) (Clark I) (1878) is a thick semi-solid compound, slightly soluble in water but soluble in chloropicrin and phosgene. As a vapour it is a strong irritant, and when diluted is aromatic.

Diphenylarsine-chlorarsine (Adamsite) (1918) is similar, but is not soluble in phosgene. It tarnishes metals (D.A. does not), is easier to manufacture, and the toxic effects last longer.

These arsenic compounds are employed as mists or clouds. Both Groups I and II are easy to detect.

Vesicants

Lewisite (chlorovinyl-dichlorarsine), first made in America in 1918 and not hitherto used in warfare, is a

heavy oily liquid darkening on standing. It is easier to detect than mustard, which in low concentrations may produce its effects before its presence is realized. The slight odour of lewisite resembles geraniums. It is soluble in oils, benzene, and the ordinary organic solvents. It is insoluble in water, but hydrolyses rapidly. This action is increased by heat and alkalis. The blistering concentration is given as 0.334 mg. per litre, which theoretically makes it an effective war gas. However, as it is so rapidly destroyed by water or aqueous vapour, and has not yet been put to a practical test, it is unlikely to be used in war. Lewisite is persistent, but less so than mustard.

Mustard (dichlorodiethyl sulphide) was first used by the Germans in 1917, and manufacture of this substance by us was not completed until almost the end of the war. As in the case of chlorine, our Intelligence Service secured early information, the full meaning of which was, however, only understood at a later date. Mustard is a heavy oily liquid, in the pure state colourless and almost odourless. In quantities as produced commercially it is dark in colour and smells of mustard or garlic. It is highly persistent, and stable at ordinary temperatures. Heat causes decomposition into HCl and highly toxic lacrimators. Contact with water causes slow hydrolysis, which is hastened by heat. The resulting products are harmless—dilute HCl and thiodiglycol. Since its specific gravity is 1.280 at 15° C., it readily sinks when added to water. Weathering will thus ultimately destroy mustard. Hypochlorites react violently with mustard, producing a non-toxic sulphoxide. This explains the use of "bleach" calcium hypochlorite.

Mustard is soluble in water to less than 1 per cent., but is freely soluble in the hydrocarbon oils, such as paraffin or petrol, and substances such as animal fats, ether, benzene, alcohol, acetone, carbon disulphide, etc. It is also readily dissolved in rubber, and permeates clothing, leather, wood, bricks, etc., like ink on blotting-paper. This property of penetration into most materials other than metals and substances with a glazed surface renders its destruction especially difficult. Mustard has a low vapour pressure, which explains why it vaporizes so slowly and is so persistent, and also the varying effects according to the temperature and humidity of the atmosphere.

This is the gas most to be expected in war. Of 36,965 gas casualties in the American Army, 27,711 were due to mustard (Vedder), and of the 160,970 gas casualties admitted to the casualty clearing stations of the B.E.F. 77.7 per cent. were due to the same cause. Exposure to a concentration of 1 in 1,000,000 is effective.

Lung Irritants

Chlorine is a greenish gas, 2.5 times as heavy as air; it therefore clings to the ground and fills hollows. It is easily liquefied; one litre of liquid chlorine at 25° C. will produce 434 litres of gas. Its pungent smell is well known. It is non-persistent. Pure dry chlorine will not corrode steel.

Phosgene (COCl₂; C.G.; carbonyl chloride or carbon oxychloride) is the most effective and lethal of the pulmonary irritants, but fortunately is completely resisted by the respirator. It is a liquid, boiling at 8.2° C. (46.8° F.). It is colourless, smells of "musty hay," and is 3.5 times as dense as air. It is non-persistent, and is easily moved on by the wind. Phosgene is readily hydrolysed, so that it cannot be employed in damp or rainy weather. The hydrochloric acid liberated in the presence of moisture

corrodes steel, damages clothing, and destroys the tissues of the lungs. Soda-lime is used in the canister of the respirator to absorb phosgene. Phosgene will dissolve several of the toxic gases, and mixtures of mustard, chloropicrin, and the arsenic smokes may be expected. This gas is liquefied easily, as in the case of chlorine. *Diphosgene* (perstoff, superpalite, or trichloromethyl-chloroformate) is an oily liquid boiling at 128° C. It is heavier than phosgene, has the same toxicity, and is an intense lacrimator.

Chloropicrin (P.S.)—nitrochloroform—is a colourless volatile liquid, not hydrolysed by water, and semi-persistent. It also is a lacrimator. It is heavier than water, boils at 112° C., and is approximately 5.5 times heavier than air. It is killed by a solution of sodium sulphite in 50 per cent. alcohol. It has a penetrating odour and is strongly irritant. Exposure to frequent low concentrations may induce attacks of asthma.

Paralysants—These substances are not of much practical use in warfare.

Carbon Monoxide.—The management of carbon monoxide poisoning will not be dealt with in this paper.

Gas-detection Table

The following simple hints have been already published (*Pocket Book of First Aid in Accidents and Air Raids*, second edition, 1939, G. Gill and Son).

Part of Body Affected	Appearance	Smell	Chief Action	Gas
Eyes and nose	Vapour	Pungent	Tears	Lacrimator
Nose and throat	Mist	Faintly fruity	Sneezing	Sternutator
Lungs	Colourless	Musty hay	Cough	Phosgene
"	Green cloud	Pungent	Delayed collapse	Chlorine
Skin	Oily liquid	Garlic	Blisters	Mustard
"	Vapour nil	Geraniums	Redness and blisters	Lewisite

Chemical Analysis

In the issue No. 10 of volume 56 of *Chemistry and Industry*, published in 1937, appears a very important seven-page paper on analysis for the detection of poison gases by Studinger and Müller, translated by Mr. F. G. Crosse, F.I.C., from an article in "Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung und Hygiene," 1936. Some of the items of chief interest are described in the following paragraphs.

PREPARATION OF THE SAMPLE

Visible drops are soaked up in filter papers held in forceps or ether extracts are made from contaminated soil. All operations are carried out in a fume cupboard, the operator wearing a respirator if necessary. Phosgene is detected by the reagent mentioned in C.I. below.

PRELIMINARY TESTS

(1) Using small test-tubes, the boiling-point is detected. (2) Decomposability in water: a capillary loop of the extract is heated with about 0.5 c.cm. of water and tested with a 5 per cent. solution of AgNO_3 . Mustard decomposes slowly; chloropicrin and the arsines do not decompose. (3) Tests for halogens in aliphatic compounds or in the side chain of the aromatic poison gases. (4) Pringsheim's test: a mercuric chloride test paper is coloured yellow by AsH_3 . (5) Testing for nitrogen and sulphur: (a) the Prussian-blue test; (b) sodium nitroprusside—2 drops of 10 per cent. solution are added to the substance under test after being heated with sodium, a violet coloration indicating sulphide (mustard).

From Tests 4 and 5 poison gases can be classified:

C.I.—Gases resembling chlorine only: xylene bromide, chloro-acetophenone, palite (chlorine-phosgene).

C.II.—Gases containing chlorine and sulphur. Mustard.

C.III.—Gases containing chlorine and nitrogen. Chloropicrin (HCN).

C.IV.—Gases containing chlorine and arsenic. The arsines and lewisite.

C.V.—Gases containing metal. Iron, carbonyl, lead, tetra-alkyls.

SPECIAL REACTIONS

Halogen Test.—Xylene bromide boiled with alkaline potassium permanganate solution forms phthalic acid. This is isolated by extraction with sulphuric ether. The residue is heated to 250° C. with concentrated H_2SO_4 and a little resorcinol. Excess of soda lye gives a green fluorescence.

Chloro-acetophenone (C.A.P.).—A long test, where the substance is oxidized to benzoic acid with chromic acid, then nitrated and treated with ammonia and hydroxylamine HCl solution. The presence of ammonium diamino-benzoate is shown by a red-brown coloration on immersing the tube in hot water.

Phosgene is detected as diphenylurea or by a colour test paper. Air is passed over the sample into an absorption flask containing anil-water; an immediate white turbidity is produced. This is filtered off, dried at 70° C., and its melting-point determined (235° C.). Two tests are given with prepared test papers. In the second test a green coloration indicates phosgene. The reagents required are: (1) 0.05 to 1 gramme 6-nitroso-dimethylaminophenol dissolved in 50 c.cm. of hot xylene; (2) 0.25 gramme *m*-diethylaminophenol dissolved in 50 c.cm. of hot xylene. 5 c.cm. of solution No. 1 are mixed with 1 to 2 c.cm. of solution No. 2 and put on to filter paper. This paper when held in the air above the sample turns green.

Chlorine.—One gramme of soluble starch is dissolved in 100 c.cm. of water containing 5 grammes cadmium iodide and 5 grammes sodium acetate. A filter paper moistened with this solution goes blue when chlorine is present.

Mustard.—Eleven tests are given, all but one requiring the presence of liquid mustard. Of these the simplest is the sodium iodoplatinate test paper, 2 per cent. solution. This paper in the presence of mustard or an aqueous mixture of it becomes purple-red, then blue. In this country yellow detector disks are provided which become red in the presence of liquid mustard. The chemistry of this test is secret, but it probably depends on selenium.

Grignard's test will detect the vapour of mustard. 20 grammes of sodium iodide are dissolved in a little water and an aqueous solution containing 1.65 grammes of copper sulphate is added. Into this mixture is stirred 2 c.cm. of a solution of 35 grammes of powdered gum arabic in 100 c.cm. of water. The whole is made up to 200 c.cm. and the cuprous iodide filtered off. This clear solution is stored in a brown bottle. When mustard vapour is passed through 3 c.cm. of this reagent a turbidity appears due to the formation of di-iodo-diethyl sulphide.

Chloropicrin.—Four tests are given. Of these the simplest is Labat's. One drop of chloropicrin extract is added to 2 c.cm. of 5 per cent. alcoholic potash lye. When a small crystal of thymol is dropped in a yellow colour appears. Several supplemental tests are given, which need not be described in this paper.

Summary

A sound knowledge of the chemical poisons which may be used in modern warfare is the preliminary essential to a complete acquaintance with clinical diagnosis, management, and treatment of casualties.

An intimate chemical study of all the "gases" will interest only a few experts, but a working knowledge of their physical and physiological properties should be acquired by all medical men as soon as possible.

(The second part of this article will be published next week.)