THE TOXICITY OF SCREENING SMOKES

BY

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Screening smokes, properly used, are perfectly safe. Some irritation of the throat and chest may be caused, but a properly designed smoke screen will rarely produce ill-effects from any but very prolonged or frequently repeated exposures. These chemical smokes may, however, be harmful if high concentrations are inhaled for more than brief periods, so that dangers can arise from their misuse or the accidental ignition in enclosed spaces, such as dug-outs, buildings, or tunnels. Hardly a year goes by without such an accident occurring, and the diagnosis and treatment of the casualties always seem to present difficulties to the medical officers concerned.

After a recent series of cases about which advice was sought it seemed both opportune and desirable to summarise, for the guidance of medical officers, the relevant experimental and clinical facts on the toxicity of the common screening smokes.

All chemical smoke mixtures can be respiratory irritants and therefore their main toxic effect is one of damage to the respiratory system. However, they do vary in their irritancy and therefore in the danger they present.

HCE-Smoke mixture contains equal quantities of hexachlorethane (HCE) and zinc oxide with 10 per cent calcium silicide. On ignition, a dense white smoke is produced and the possible products of combustion are zinc chloride, carbon monoxide, carbon dioxide, phosgene, hydrocarbons and chlorinated hydrocarbons. Chemical analysis of the smoke cloud, produced in an enclosed gas chamber, has shown that the carbon monoxide concentration does not exceed 0.04 per cent, that only traces of phosgene (less than 15 mg./m³) are present, and that the only constituent of the smoke likely to be harmful is zinc chloride. On an average, the efficiency of the smoke generators is such that for every 100 g. mixture used, a little over 40 g. of zinc chloride is released.

When inhaled, zinc chloride behaves as a corrosive irritant and animal experiments have shown that it will produce a severe tracheobronchitis and intense pulmonary congestion and oedema. Guinea-pigs, which are susceptible to bronchospasm, may die rapidly from this and at autopsy the lungs are markedly emphysematous. The dosage of zinc chloride required to produce death in animals is, however, fairly large. Thus the LC₅₀ for mice (i.e. the dosage, expressed as the product of the concentration and time of exposure to kill 50 per cent of the mice) has been estimated as 11,800 mg. min./m³. However, the dosage had to be reduced to 2,000 mg. min./m³ or less before no macroscopic or histological sign of lung damage was seen.

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Therefore, the highest safe dosage has been taken to be 2,000 mg.min./m$^3$, and this could be for a single exposure or a series of repeated minor exposures over a period of ten days.

Some indication of what this safety dosage means in terms of safety distances from the smoke source can be given. It has been calculated that, in a good area smoke screen at night, under suitable meteorological conditions, the concentration of zinc chloride at 200 yd. from the source would be about 85 mg./m$^3$ (therefore the subject can safely stay there a maximum of 24 minutes), and at 1,000 yd. the concentration would be about 13 mg./m$^3$ (and the maximum safety time of exposure, therefore, is $2\frac{1}{2}$ hours). In efficient flank screening by day and under suitable meteorological conditions, the zinc chloride concentration at 100 yd. from the source would be 47 mg./m$^3$ (safety time 43 minutes) and at 1,000 yd. would be 0.9 mg./m$^3$ (safety time 37 hours).

Some minor irritation may be noticed by men working in these smoke screens. Thus, in a concentration of 120 mg./m$^3$ zinc chloride from HCE-mixture, volunteers complained of irritation of the nose, throat and chest, with cough and nausea, after 2 minutes. At 80 mg./m$^3$ for 2 minutes, the majority had slight nausea, one or two coughed and all noticed the smell of the smoke. However, men working in the field for 30 minutes at 200 yd. from the source, only felt a slight burning sensation in the chest and the smoke cloud was not intolerable.

The lethal dosage for man is, of course, not known, but, on the basis of our animal experiments, it is considered to be probably greater than 50,000 mg.min./m$^3$ of zinc chloride. Such a dosage would be achieved by one generator in a 100 cu.ft. room in 2-3 minutes.

It is, in fact, usually following exposure in small, enclosed spaces, e.g. in trenches, dug-outs, tunnels and between decks in ships, that the majority of the reported casualties and deaths from HCE smoke have occurred. Occasionally men have been affected in the open but then usually not seriously.

Affected men usually complain of pain in the chest and abdomen, difficulty in breathing and nausea. They cough continuously and there may be vomiting. Lachrymation and conjunctivitis may be seen. Dyspnœa and cyanosis become progressively more marked and the clinical picture varies with the concentration of the smoke.

In exceedingly high concentrations, such as have resulted from the spontaneous ignition of smoke generators in a tunnel, death may occur rapidly from asphyxia due to œdema of the larynx and spasm of the glottis. In lesser but still very high concentrations death may occur in a few hours from severe hæmorrhagic ulceration and excoriation of the upper respiratory tract.

With smaller but still high dosage the cause of death is usually pulmonary œdema, with less severe damage to the upper respiratory tract. Death in these cases usually occurs within 24 to 48 hours. Those dying later show, at autopsy, some damage to the bronchial mucosa, moderate pulmonary œdema and a superimposed bronchopneumonia.

Animal experiments suggest that the injection of BAL will aid the excretion
of zinc and so protect against zinc chloride poisoning. The respirator gives complete protection against HCE smoke.

**Chlorsulphonic Acid Smoke (C.S.A.).** The mixture used is 50/50 w/w of chlorsulphonic acid (SO₄(OH)Cl) and Sulphur trioxide (SO₃). It gives a screening cloud consisting largely of sulphuric acid droplets, with little chlorine or hydrochloric acid. The chemical concentration of an effective screen, in terms of sulphur trioxide content, is probably not greater than 30 mg./m³.

Cameron (1954) has reported experiments in which he exposed a variety of animal species—monkey, goat, rabbit, guinea-pig, rat and mouse—to maintained concentrations (30 and 60 mg./m³ in terms of SO₃ content) for 6 hours a day over periods of 7 to 14 days. Only one species, the guinea-pig, proved susceptible, dying from bronchial spasm, pulmonary oedema, and acute bronchitis. He concluded that the chief risk when human beings are exposed to chlorsulphonic acid smokes in these concentrations will be found in persons susceptible to bronchial spasm; that is, those who suffer from asthma or allied conditions. Persons not subject to pulmonary disturbances should suffer no ill-effects.

The concentrations used in the above experiments would probably be similar to those experienced 500 yd. astern of the point of emission with a head wind of 5 m.p.h. and a ship steaming at 5-10 knots. These concentrations, although not permanently harmful, are intensely irritating. A “burning” or “tight” sensation in the throat and chest with coughing is experienced by most subjects, although many become accustomed to the smoke and can then remain in the cloud. With higher concentrations the symptoms are more distressing and no one would voluntarily stay in those denser smokes without adjusting his respirator, which gives complete protection. The severity of response does, however, vary from subject to subject. Thus, in one series of experiments, involving exposures of 2 minutes duration, the concentration (expressed as C.S.A.) had to be raised to 855 mg./m³ before wearing of respirators was enforced in all exercising subjects and to 1,220 mg./m³ before all the subjects at rest had to don their respirators. At these concentrations eye irritation, burning, sensations in the throat and chest, coughing, profuse salivation and distressing nausea were the symptoms produced. Some subjects actually experienced explosive coughing and were unable to adjust their facepieces. This could be dangerous in certain circumstances since prolonged and unprotected exposure to such high concentrations could undoubtedly cause severe corrosive and irritative lesions in the respiratory tract. Normally, however, the irritation caused by this smoke would warn men to seek the protection of their respirators or to move out of the cloud.

**Titanium tetrachloride** is another corrosive substance which can be used for producing smoke screens. In general it is less toxic than C.S.A. but more irritant than HCE. The pathological effects produced in animals which have died from the inhalation of large quantities of this substance are similar to those described for HCE and C.S.A.

Sometimes the question is asked as to the danger of grazing stock on land contaminated with titanium tetrachloride. The latter discours green leaves and stock will usually avoid these if non-contaminated land is available.
cows, sheep, goats and horses can be fed on hay from a contaminated area and they will suffer no ill-effects. The titanium is not absorbed from the gastrointestinal tract but passes harmlessly through to be excreted in the faeces.

*White phosphorus.* This may present a double hazard to troops since it has been used to produce screening smokes and also as an incendiary agent. The smoke may produce irritation of the throat and can induce coughing but, compared with C.S.A., it is not unduly harassing. Experiments have shown that a concentration of $700 \text{ mg./m}^3$ is required before the effects compel men doing moderate work to adjust their respirators; $1,770 \text{ mg./m}^3$ is needed to harass men similarly at rest. Even with concentrations as high as $3,600 \text{ mg./m}^3$ it is impossible to produce explosive coughing and so hinder the adjustment of facepieces.

Personnel may be burnt when ignited lumps of phosphorus fall on them. On burning there is immediate pain and rapid vesication occurs; erythema usually fades within 24 hours. In order to be certain of producing vesication of the skin through two layers of clothing in tight contact with the skin a particle of phosphorus weighing about $100 \text{ mg.}$ is required unless, of course, the immediate pain and smoke and flames produced cause the person to take quick remedial action. For third degree burns particles more than $1 \text{ g.}$ in weight are needed, and a similar sized particle is required to burn through damp clothing.

These phosphorus burns closely resemble thermal burns in their pathological history. There is little reason to anticipate absorption of phosphorus, with the production of general systemic phosphorus poisoning, since only minute amounts of free phosphorus persist for a short period in the burnt areas and the chances of absorption of such phosphorus from the tissues are slight. Oily material may, however, lead to absorption and should be avoided in all treatments.

For first-aid treatment a copper sulphate-soft soap ointment is useful. It is easy to apply, soothing, rapidly puts out the flame and renders the phosphorus particles readily visible.

Perhaps it should also be mentioned that land which has been contaminated by phosphorus-containing missiles may be dangerous to grazing livestock. Small pellets of phosphorus can be driven into tufts of grass so that, by the exclusion of air, combustion may not be complete. This phosphorus if eaten will, of course, produce toxic effects.

**REFERENCE**