Health consequences of large scale use of tear gases and other chemical substances in mass gatherings as a means for law enforcement.

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Tear gas and other chemical substances have gained widespread acceptance as a means of controlling civilian crowds and subduing barricaded criminals. The most widely used forms of tear gas have been o-chlorobenzylidenemalononitrile (CS), chloroacetophenone, (CN), dibenzoxazepine (CR) and oleoresin capsicum (OC). Proponents of their use claim that, if used correctly, the noxious effects of exposure are transient and of no long-term consequences. The use of tear gas in recent situations of civil unrest, however, demonstrates that exposure to the weapon is difficult to control and indiscriminate and the weapon is often not used correctly. Severe traumatic injury from exploding tear gas bombs as well as lethal toxic injury have been documented. More over, available toxicological data are deficient as to the potential of tear gas agents to cause long-term pulmonary, carcinogenic, and reproductive effects. Published and recent unpublished in vitro tests have shown o-chlorobenzylidenemalononitrile to be both clastogenic and mutagenic. Sadly, the nature of its use renders analytic epidemiologic investigation of exposed persons difficult. In 1969, eighty countries voted to include tear gas agents among chemical weapons banned under the Geneva Protocol. There is an ongoing need for investigation into the full toxicological potential of tear gas chemicals and renewed debate on whether their use can be condoned under any circumstances.

Keywords: tear gases mass gatherings CS CN CR pepper spray (OC)

Η χρήση δακρυγόνων και άλλων χημικών ουσιών έχει πλέον κερδίσει ευρεία αποδοχή ως ένα μέσο ελέγχου μαζικών συγκεντρώσεων και ατόμων με παραβατική συμπεριφορά. Οι πιο διαδεδομένες μορφές δακρυγόνων είναι το o-chlorobenzylidenemalononitrile (CS), το chloroacetophenone, (CN), το dibenzoxazepine (CR) και το oleoresin capsicum (OC) γνωστό και ως σπράυ πιπεριού. Οι υπέρμαχοι της χρήσης αυτών των ουσιών, υποστηρίζουν πως αν χρησιμοποιηθούν σωστά, οι επιβλαβείς επιπτώσεις από την έκθεση σε αυτές είναι παροδική και χωρίς μακροπρόθεσμες συνέπειες. Η χρήση όμως δακρυγόνων σε επεισόδια και καταστάσεις πολιτικών αναταραχών, δείχνει ότι η έκθεση σε αυτές τις χημικές ουσίες είναι δύσκολο να ελεγχθεί, είναι αδιάκριτη και σε πολλές περιπτώσεις τα χημικά αυτά δε χρησιμοποιούνται σωστά. Σοβαροί τραυματισμοί από έκρηξη βομβών δακρυγόνων αερίων καθώς και θανατηφόροι τοξικοί τραυματισμοί έχουν τεκμηριωθεί. Τα διαθέσιμα τοξικολογικά στοιχεία ως προς τις δυνατότητες των δακρυγόνων αερίων να προκαλέσουν μακροχρόνιες επιπτώσεις στο αναπνευστικό σύστημα, στην αναπαραγωγή καθώς και καρκινογόνες μεταλλάξεις, είναι ανεπαρκή. Δημοσιεύθηκαν πρόσφατα δοκιμές in vitro που δείχνουν ότι το o-chlorobenzylidenemalononitrile (CS) μπορεί να είναι τόσο κλαστογόνο (ρήξη χρωμοσωμικής δομής) όσο και μεταλλαξιογόνο. Δυστυχώς, η φύση της χρήσης του καθιστά την αναλυτική επιδημιολογική έρευνα των εκτεθειμένων προσώπων πολύ δύσκολη. Το 1969, ογδόντα χώρες ψήφισαν να περιλαμβάνονται τα δακρυγόνα αέρια μεταξύ των χημικών όπλων που έχουν απαγορευθεί βάσει του πρωτοκόλλου της Γενεύης. Υπάρχει μια συνεχής ανάγκη για έρευνα σχετικά με το πλήρες τοξικολογικό δυναμικό των δακρυγόνων χημικών αερίων καθώς και κατά πόσο η χρήση τους μπορεί να θεωρηθεί δικαιολογημένη σε κάποιες περιπτώσεις.

TEAR gas is a weapon that has become familiar to the world. Hardly a week goes by without press reports of tear gas being used in a public setting, typically the dispersal of demonstrators or the subdual of a barricaded criminal. Recent years have seen the use of large amounts of tear gas in several countries, including Chile; Panama; South Korea; and the Gaza Strip and West Bank, Israel. Liar gas is actually the common term for a family of chemical compounds that have been otherwise referred to as "harassing agents" because of their ability to cause temporary disablement. Some 15 chemicals have been used worldwide as tear gas agents. Six of these- chloroacetophenone (CN), o-chlorobenzylidenemalononitrile (CS), 10-chloro-5, l0-dihydrophenarsazine, bromo-tolunitrile, dibenzoxazepine (CR) and pepper spray (OC) have been used extensively. (1) In the United States, Britain, and Europe, CN and CS have been employed most widely. o-Chlorobenzylidenemalononitrile (CS), in particular, is a weapon that has gained widespread acceptance as a means of controlling civilian populations during disturbances.

The widespread use of tear gas agents naturally raises the question of their safety. Relatively little, however, has appeared in the mainstream medical literature regarding their toxicology. In general, authors of review articles have averred that, if used correctly, the noxious effects of exposure are transient and of no long-term consequence. (2,3,4). Much emphasis has been given to the findings of the Himsworth Report, (5) the results of an inquiry by a committee appointed by the British Secretary of State for the Home Department following the use of CS in Londonderry, Northern Ireland, in 1969. In addition to investigating the use of CS in

Londonderry, the committee reviewed a wide range of scientific data. Its main conclusion was that while exposure to CS can be lethal, most likely in the form of toxic pulmonary damage leading to pulmonary edema, such an occurrence would only be at concentrations that were several hundred times greater than the exposure dosage that produces intolerable symptoms. Many questions remain, however. Epidemiologic inquiry following the use of tear gas under actual field conditions has been almost completely absent.

CS AND OTHER TEAR GAS AGENTS

While poisonous gases have been used sporadically in military history as early as 428 BC, when burning wax, pitch, and sulfur were used in wars between the Athenians and Spartans, it took the birth of the modern chemical industry and the circumstances of World War I for the invention of chemical warfare agents to begin in earnest. Agents that could temporarily incapacitate victims were among the first to be developed and were deemed "harassing agents." Of these, chemicals that produce lacrimation and uncontrollable blepharospasm, otherwise known as "tear gas agents," became the most popular.

Harassing agents are capable of a number of immediately perceived effects: intense irritation of the eyes, causing crying or temporary blindness; irritation of the mucous membranes of the nose, trachea, or lungs, causing coughing; irritation of the throat and stomach, with the induction of vomiting and possibly diarrhea; and irritation of the skin. Most harassing agents will cause several or all of these reactions to a greater or lesser extent.

For many years, CN was the most widely used agent by civil and military authorities. It is the active ingredient in Mace and is still used in many parts of the world. Dissatisfaction with its potency and chemical instability, however, led military scientists to search for alternative agents.

In the 1950s, the Chemical Defence Experimental Establishment (Porton, England) developed CS. o-Chlorobenzylidenemalononitrile is a white crystalline substance that is usually mixed with a pyrotechnic compound in a grenade or canister for use. Its useful form is intended to be a smoke or fog of suspended particles. Effectiveness in crowd control derives from its properties as an extremely severe skin and mucous membrane irritant and lacrimator, even at minute doses. Instantaneous conjunctivitis with concomitant blepharospasm, burning, and pain are characteristic. These symptoms are exacerbated in hot or humid weather. o-Chlorobenzylidenemalononitrile that has been micronized and mixed with an antiagglomerant or treated with a silicone water repellent (formulations known as CS1 and CS2, respectively) can remain active for days to weeks when dusted on the ground.

Since its introduction, CS has virtually replaced CN as the riot control agent of choice in England and the United States. During the Vietnam war, the United States developed an array of delivery vehicles for CS, including small pocket grenades, the "Mighty Mite" (a continuous-spray device used in caves and tunnel systems), and 58 kg cluster bombs dropped from helicopters and planes.

TOXICOLOGY OF CS

Military studies among volunteers have noted that, in most cases, removal from exposure to CS results in fairly rapid recovery with cessation of all symptoms within minutes (6). Proponents of the use of CS believe that, when used properly, high or prolonged exposure to the substance would be precluded by an individual's natural aversion to remaining in an area where the substance is present (United Kingdom patent specification 967 660; 1960). Its popularity among military and police authorities stems partly from comparisons with the other tear gas agents, which suggests that CS is a more potent lacrimator and seems to cause less long-term injury, particularly with respect to the eye.

Inhalation toxicology studies (7,8,9) at high levels of CS exposure, however, have demonstrated its ability to cause chemical pneumonitis and fatal pulmonary edema. In situations in which high levels of exposures have occurred the same effects, as well as heart failure, hepatocellular damage, and death, have been reported in adults. (5,10). An infant exposed to CS in a house into which police had fired CS canisters to subdue a mentally disturbed adult developed severe pneumonitis requiring therapy with steroids, oxygen, antibiotics, and 29 days of hospitalization. (11).

The respiratory concentration of CS that would be lethal for 50% of healthy adults has been estimated to be 25 000 to 150 000 mg/m3 per minute, based on animal studies. (12).

When detonated outside, a CS grenade generates a cloud 6 to 9 m in diameter, at the center of which a concentration of 2000 to 5000 mg/m3 can be produced, with concentrations rapidly tapering off et the periphery. (13).

If detonated in an enclosed space or in clusters, however, much higher levels of exposure could be expected. Moreover, chemical weapons have generally been noted to be notoriously uneven in their dispersal (14).

Oral toxicology studies (15,16) have noted the ability of CS to cause severe gastroenteritis with perforation. Metabolic studies indicate that absorbed CS is metabolized to cyanide in peripheral tissues.

The potential for CS exposure at levels seen in the field to result in significant generation of cyanide at the tissue level is controversial (17,18,19) Authors who downplay this possibility reason that one would have to inhale massive quantities that could only occur if the gas were used improperly, and that severe pulmonary injury would overshadow the effects of cyanide generations ever, this argument ignores the ingestion of tear gas chemical that can occur with pharyngeal deposition of incompletely dispersed CS compound and swallowing of respiratory secretions.

Contact burns and the development of skin sensitization with contact dermatitis have been described in a number of experimental and observational studies on animals and humans (13,20,21,22). This is in keeping with the many skin burns encountered during our inquiry.

Studies have not adequately examined the possibility that CS at less than high concentrations can cause lasting pulmonary effects. One study (8) of CS exposure on volunteers showed no increase in airway resistance following several exposures. However, only seven healthy military recruits were examined and volunteers with a history of asthma were excluded. Previous studies have shown that single exposures to high levels of respiratory irritants similar to CS have been associated with the development of reactive airways disease syndrome in some individuals (23). The symptoms of prolonged cough and shortness of breath that were reported in our community survey suggest that such an effect may have occurred as a result of CS exposure in South Korea.

Only one study (24) has assessed the effect of CS on pregnancy in animals and it found no significant effect. The Himsworth committees (5) found no significant increase in abortions, stillbirths, or congenital abnormalities in geographic districts of tear gas use, comparing a 9 month period of heavy tear gas exposure to a previous 9 month period. More sophisticated epidemiologic studies do not exist.

POTENTIAL FOR GENOTOXICITY

The agent CS can alkylate sulfhydryl groups and, possibly, DNA (25,26,27). As such, it is potentially genotoxic. The agent has not, however, been well studied for its genetic effects in vitro or in vivo. Some researchers have shown CS to be mutagenic in both Ames Salmonella assays (27) and in the L5178Y tk+/tk-mouse lymphoma forward mutation assay (28). Zeiger et al., (29) reported CS to be questionably mutagenic in the Ames assay, testing l ower doses than Von Daniken et al. (27). When Von Daniken et al accounted for the toxicity of CS, its mutagenic effects increaseed by a factor of 2. Thus, the toxicity of this agent can make it difficult to study in vitro. Cytogenetic testing done by the National Toxicology Program (unpublished data, 1988) and the National Institute of Environmental Health Sciences has shown CS to be clastogenic in Chinese hamster ovary cells and to induce sister chromatic exchanges in these same mammalian cells. Other researchers (30,31) have reported negative results in testing CS for mutagenicity on the Ames test. A single study (27) of animal embryos did not reveal any teratogenic effects of CS.

The agent CS has been found to suppress nonspecific esterase activity in mouse skin sebaceous gland (32,33). This property has been suggested for use as a screening test for the carcinogenic potential of suspected chemicals (33). A study (34,35) of the carcinogenicity of CS in A/J strain mice and Sprague-Dawley Wistar rats done at the Edgewood Arsenal reported CS to induce more pulmonary tumors in exposed animals after 4-week inhalation experiments, conducted at 0, 50, and 500 mg/m3 per minute. The increase, however, was not strictly dose related and of borderline statistical significance. This report concluded that CS was not significantly tumorigenic in these animals, but observed that chronic exposure to very low concentrations of CS is of greater concern and should be further studied. In addition, Marrs et al (35) studied the inhalation toxicity of CS in rodents. Owing to the limited number of animals studied, they were also unable to draw a firm conclusion concerning the tumorigenicity of CS.

TOXICITY OF CN, CR and pepper spray (OC)

Although CS has been the most widely used and well studied of the tear gas agents, other agents are still available. Of particular importance is CN, which is still being produced in the United States (36) and was reported to have been used in the West Bank and Gaza Strip (37) **-Chloroacetophenone (CN)** is generally acknowledged to be of greater toxicity than CS, being more likely to cause permanent corneal damage on contact with the eye (16) and primary and allergic contact dermatitis (38,39). The maximum safe inhaled dose has been estimated to be several times lower than that of CS (3) and at least five deaths have been reported following the use of CN grenades in confined spaces (2,40,41). Little is known regarding its potential for chronic pulmonary or genotoxic effects or for potential effects on reproduction.

CR gas or **dibenzoxazepine**, is an incapaciting agent and a lachrymatory agent. CR was developed by the British Ministry of Defence as a riot control agent in the late 1950s and early 1960s. CR is a pale yellow crystalline solid with a pepper-like odour. It is slightly soluble in water and does not degrade in it. CR is usually presented as a microparticulate solid, in the form of suspension in a propylene glycol based liquid. Contrary to its common name, it is not actually a gas but is solid at room temperature. It is chemically related to loxapine, a typical antipsychotic drug. CR is loxapine's parent compound. It was first synthesised in 1962.[1]These gases are usually fired in canisters (LACR) that heat up, producing an aerosol cloud at a steady rate. CR gas is a lachrymatory agent (LA). Its effects are approximately 6 to 10 times more powerful than those of CS gas. CR causes intense skin irritation, particularly around moist areas, blepharospasm causing temporary blindness, coughing and gasping for breath, and panic. It is capable of causing immediate incapacitation. It is a suspected carcinogen. It is toxic, but less so than CS gas, by ingestion and exposure. However, it can be lethal in large quantities. In a poorly ventilated space, an individual may inhale a lethal dose within minutes. Death is caused by asphyxiation and pulmonary edema.The effect of CR is long-term and persistent. CR can persist on surfaces, especially porous ones, for up to 60 days.

Oleoresin capsicum (OC). OC, a naturally occurring substance derived from the cayenne pepper plant, is classified as an inflammatory agent. On contact with OC, the mucous membranes of the eyes, nose, and throat immediately be- come inflamed and swollen. The symp- tomatic swelling produces involuntary eye closure due to dilating capillaries; nasal and sinus drainage; constricted air- way; and temporary paralysis of the larynx, causing gagging, coughing, and shortness of breath. The extract of peppers causes the blood vessels to dilate and the blood to rush to the upper body; (42,43,44) the skin appears inflamed, resembling a burn. OC’s inflammatory properties purportedly render the agent more effective than CN and CS on violent, intoxicated, drugged, and mentally ill individuals. Moreover, the symptomatic eye closure and con- striction of the respiratory tract explain why OC is so effective on animals. No special decontamination protocols are required for OC because it is biodegradable. Unlike CN and CS irritants, OC will not persist on clothing or af- fected areas.Examination of a national sample of in-custody deaths that occurred subse- quent to OC use has excluded the agent as a contributory factor. This analysis concluded that, to date, OC has not caused any deaths.1 Finally, OC use does not result in dermatitis, skin depigmentation, or burns.

TREATMENT

Most exposures to CS, CN and CR typically cause immediate and severe irritation of the eyes and respiratory tract, accompanied by blepharospasm, lacrimation, coughing, sneezing, and rhinorrhea, followed rapidly by a burning sensation of exposed skin surfaces and the mouth. Some persons also experience nausea and vomiting, photophobia and headache. These symptoms usually disappear within a few hours after removal from exposure.

Clinically, signs of exposure consist of blepharospasm, conjunctival injection palpebral edema, and lacrimation. Management is conservative, beginning with aeration and the disposal of all contaminated clothing in plastic bags. Skin should be washed, although contact with water can briefly exacerbate skin symptoms from CS exposure, and a mild alkaline solution (6% sodium bicarbonate, 3% sodium carbonate, and 1% benzalkonium chloride) has been recommended to hasten decontamination of CS (13). Persistent eye irritation can be relieved with application of a local anesthetic preparation and a patch. Contact dermatitis may respond to corticosteroid creams and antipruritics.

Exposure to high concentrations of tear gas by inhalation or ingestion, as may occur in an enclosed space or in proximity to an exploding tear gas device, should be treated cautiously. Pulmonary injury with edema can be delayed and the patient should be kept under observation for several days. Initial treatment may begin with humidified oxygen; bronchodilators and ventilator therapy may be necessary. Prophylactic antibiotics have been suggested (2). We believe a thiocyanate assay should be considered in cases of ingestion or extremely high exposure.

Persons with preexisting lung disease such as asthma or emphysema should be observed carefully for exacerbation of their condition.

COMMENT

From a toxicological perspective, there is a great need for epidemiologic and more laboratory research that would illuminate the full health consequences of exposure to tear gas compounds such as CS. The possibility of long-term health consequences such as tumor formation, reproductive effects, and pulmonary disease is especially disturbing in view of the multiple exposures sustained by demonstrators and non-demonstrators alike in some areas of civilian unrest. The development of tolerance to CS, a phenomenon that has been confirmed in studies of human volunteers (45) has likely increased the length and intensity of exposure sustained by some individuals. Unfortunately, the same social conditions that accompany political unrest and the use of tear gas make epidemiologic research difficult, if not impossible.

We also believe, however, that the evidence already assembled regarding the pattern of use of tear gas, as well as its toxicology, raises the question of whether its further use can be condoned under any conditions. Fact-finding missions to areas of civil unrest in addition to

South Korea have frequently observed security forces using tear gas against peaceful demonstrators and not uncommonly against civilians in no way involved in protests (46).

We recognize it is not adequate for health professionals simply to study and reject as "medically unacceptable" every modality of riot control. As with many hazards-for example, asbestos, industrial toxic emissions, or radiation-there is an important role for the independent professional: to study, document, analyze, and report on such hazards and to advise government on what does and does not carry an acceptable risk. If a weapon is found to present too serious a risk, it is then the responsibility of those in charge of public safety to decide on alternatives. In doing so, active consultations should be sought with medical and public health specialists who are independent of law enforcement agencies and, ideally, drawn from both governmental and non-governmental agencies and institutions. In the United States, for example, health specialists might be recruited from medical school faculties, state and local health departments, the Public Health Service, and the Centers for Disease Control.

At a time when the world has recently seen the recurrence of the use of mustard gas, this time in the Middle East, it is also worthy to note that in 1969, at the United Nations General Assembly, 80 countries voted to ban the use of any chemical in war, including tear gas, under the Geneva Protocol (47).

Finally, we have been persuaded that in many instances in which harassing agents have been used, dialogue and negotiation could have been pursued. Often, public order might be better served if riot police are not called immediately to duty. It is the hallmark of repressive regimes to equate the voicing of dissent with disorder and to deny opponents the freedom of assembly and speech, rights guaranteed universally among signatories to the Universal Declaration of Human Rights."

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