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Chemical and Biological Weapons

The U.S. has renounced all forms of biological weapons and the first use of most chemical weapons. The issue of whether or not to include irritant gases and antiplant agents in the prohibition remains open

by Matthew S. Meselson

On November 25 of last year President Nixon announced a number of major decisions regarding chemical and biological weapons. He proclaimed that the U.S. will never be the first to use lethal or incapacitating chemical weapons and will not use biological weapons under any circumstances, even in retaliation. He also announced that he would submit to the Senate the 1925 Geneva Protocol prohibiting the use of chemical and biological weapons in warfare.

The President's statement left a question whether toxins, the poisonous but nonliving substances produced by some bacteria and other organisms, were included in the unconditional renunciation of biological weapons or only in the no-first-use pledge for chemicals. The question was resolved on February 14 when the President extended the policy for biological weapons to cover toxins as well. In order to remove a possible ambiguity, it was decided to renounce toxin weapons even if advances in chemistry should make it practicable to prepare them synthetically instead of by extraction from bacteria or other organisms.

Under the new policy the U.S. will destroy existing stocks of germ and toxin weapons and will no longer engage in their development, production or stockpiling. The U.S. biological program will be restricted to research for strictly defined defensive purposes, such as techniques of immunization.

In accord with these decisions on biological and toxin weapons, White House officials have stated that there will no longer be a need for secret work and that consideration is being given to the transfer for conversion to other purposes of our sizable biological weapons facilities at Fort Detrick, Md., and Pine Bluff, Ark., from the Department of Defense to nonsecret agencies such as the Department of Health, Education, and Welfare and the Department of Agriculture.

As to chemical weapons, the restraints are less sweeping. The U.S. reserves the right to continue the development, production and stockpiling of lethal and incapacitating chemical weapons. It pledges, however, never to use them first. The same pledge is embodied in the treaty commitment by the 84 states now party to the Geneva Protocol.

There are two types of chemical weapon whose use in war has not been renounced. They are the antiplant chemicals and the "riot control" agents, such as CS, employed by U.S. forces in Southeast Asia. The U.S. has maintained that these agents are not prohibited by the Geneva Protocol. Many nations disagree, which raises problems for U.S. ratification of that treaty. The President himself has made no statement regarding CS or herbicides. White House officials have said only that the use of these chemical weapons will continue "for the time being."

The President's decisions were based on a six-month review of U.S. policies and programs for chemical and biological weapons. The review was conducted under the auspices of the National Security Council, which coordinated the efforts of the Department of State, the Department of Defense, the Arms Control and Disarmament Agency, the Central Intelligence Agency, the Office of Science and Technology and other branches of the Government. The subject was put under searching examination. The National Security Council considered the following topics: chemical and biological weapons that were already available and those that might conceivably be developed, the possible military value of each type of weapon in relation to other weapons at our disposal, the possible consequences of proliferation, strategic questions concerning the use of such weapons for threat or deterrence, the political and moral impact of their development and possible use, the potential hazards for civilian populations, possible defenses against the various weapons, and the policies and activities of other nations.

It was obvious and became more so as the review proceeded that such a study was long overdue. The U.S. had a large factory for producing germ weapons, even though no one had ever produced a convincing "scenario" for a case in which they should be used. Shortly before and during the National Security Council study, chemical weapons were involved in one disquieting incident after another, creating a political atmosphere favorable to the questioning of previous policies. A series of earthquakes that shook the city of Denver was traced to the massive subterranean disposal of chemical wastes at the Army's Rocky Mountain Arsenal. The accidental release of nerve gas in a test of an aircraft spray tank over the Dugway Proving Ground in Utah led to the death of thousands of sheep, some of them grazing as far as 40 miles away. Then there was protest against the Army's plan to ship 12,000 tons of outmoded nerve-gas bombs across the country from Colorado to be dumped in the Atlantic. Soon afterward there was an incident in which nerve gas escaped from U.S. munitions stored on Okinawa, and it was also revealed that nerve-gas munitions were stored in West Germany. Finally there had been newspaper articles to the effect that the Defense Department was testing biological weapons in the South Pacific and had conducted open-air tests of nerve gas in Hawaii without informing state officials.

The public reaction to these incidents can be gauged from the fact that the U.S. Senate voted 91 to 0 for a resolution requiring the review by the Public Health Service of any plan for the domestic transportation or open-air testing of lethal chemical agents or of any biological warfare agents. The resolution, which is now law, also requires the Defense Department to render semiannual reports to Congress on the investigation, development, testing and procurement of all agents of chemical and biological warfare.

Here I shall discuss first the nature of chemical and biological weapons (CBW) and their military implications, then the international effort that has been made to prevent their use, and finally the present situation. Although much work on CBW has been secret, the essential facts about the weapons are now in the open literature. Particularly noteworthy is the report of a United Nations group published last year and the subsequent World Health Organization report that specifically examines the potential effects on civilian populations. The UN report was prepared by a group of 14 consultant experts nominated by their respective governments. The U.S. participant was Ivan L. Bennett, Jr., director of the New York University Medical Center and former Deputy Director of the U.S. Office of Science and Technology. The American members of the WHO consul-

HERBICIDES ARE SPRAYED by U.S. Air Force planes in South Vietnam. More than 19,000 sorties have been flown since 1962. One aircraft covers a swath nearly 300 feet wide and 10 miles long. Military officials say destruction of crops in certain areas held by Vietcong reduces food supplies for opposing forces and jungle defoliation reduces concealment.

tant group were Joshua Lederberg of the Stanford University School of Medicine and myself. Even more detailed than the UN and WHO reports is the forthcoming study by the Stockholm International Peace Research Institute.

Although chemical and biological weapons are linked together in the psychology, the customs and the international law that restrain their use, it is helpful to distinguish several categories for analyzing military characteristics and implications. I shall discuss five kinds of weapon: lethal biological weapons, incapacitating biological weapons, lethal chemical weapons, incapacitating chemical weapons and antiplant agents. The distinction between lethal and incapacitating is not altogether clear-cut, particularly under the extremely uncontrolled conditions of warfare. There is a continuous spectrum of agents from the highly lethal to the generally nonlethal, and even tear gas can be used together with bullets and bombs to increase casualties. Nonetheless, the arguments for and against lethal and nonlethal weapons deserve separate attention.

Let us first consider lethal biological weapons. They would operate by disseminating clouds of disease germs over the target area or upwind from it. The germs would then be inhaled by the target population. The disease anthrax is an example. Caused by the bacterium *Bacillus anthracis*, it is mainly encountered as a disease of domesticated animals that is occasionally transmitted to man. Because it is not very contagious among humans, natural cases of anthrax are generally localized rather than epidemic. If the bacteria were sprayed in the air in an aerosol, however, the effects could be devastating. The inhalation of approximately 50,000 spores of *B. anthracis* (total weight less than a millionth of a gram) is believed to be enough to cause a 50 percent chance of contracting pulmonary anthrax. Symptoms would first appear about a day after the attack. The onset might be mistaken for a common cold, but this would be followed by severe coughing, cyanosis, respiratory failure and death. Untreated pulmonary anthrax is almost always fatal.

The WHO report gives estimates of the area-coverage capability of various biological agents. For illustrative purposes the report assumes that one light bomber delivers in a single pass ground-functioning "bomblets" containing a total of 50 kilograms of dry powdered agent along a two-kilometer line at right angles to the wind. It is assumed that the intensity of atmospheric turbulence is less than a certain level, but not so low as to be at all unusual, particularly at night. The bomblets release the agent as an aerosol, which then drifts over the target area. Such calculations take into account the dissemination efficiency of the bomblets, the decay rate of agent infectivity, the rate of vertical dilution in the atmosphere, the rate of deposition on the ground and the dose-response curve for man. For an attack with anthrax spores the WHO report predicts a high mortality rate over at least 20 square kilometers. Although there are uncertainties in the quantities that enter into the calculation, the estimate is deliberately conservative. The UN report, in a similar estimate, considers an attack by a large low-flying bomber dispensing 10,000 kilograms of agent along a 100-kilometer line by means of a spray tank. The estimated area in which a high casualty rate would occur is as large as 100,000 square kilometers, depending on the particular agent used.

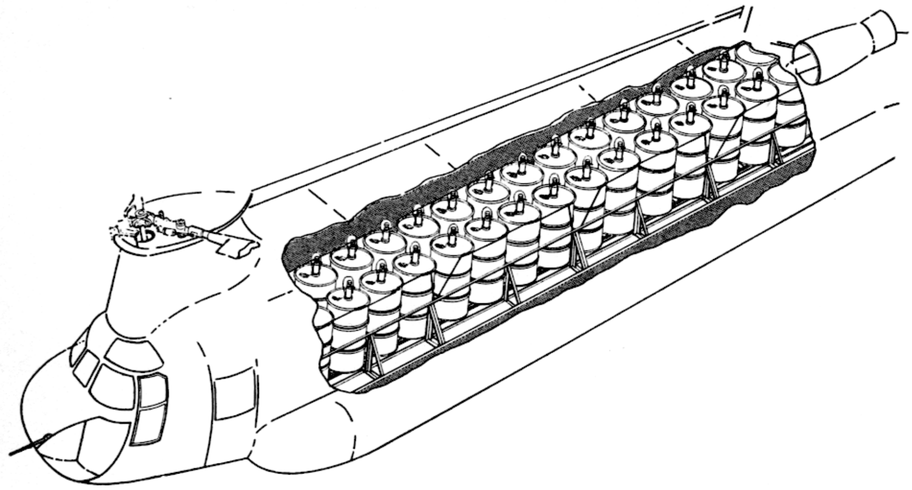
Among the lethal biological agents that might be considered for military use are the viruses of Eastern equine encephalitis and yellow fever, the rickettsia causing Rocky Mountain spotted fever, and the bacteria causing anthrax, plague, cholera, glanders and melioidosis. There are moderately effective vaccines and antibiotics against some of these diseases but none against others. Moreover, such protections might be overwhelmed by a massive attack, and for some agents antibiotics can be circumvented by the use of drug-resistant strains. Protection can be given by gas masks or air-filtered shelters if there is early warning of an attack, but no satisfactory early-warning device has yet been developed. In any case a program for supplying the civilian population with masks and shelters and maintaining discipline for their use would require a major and sustained economic and political effort—without achieving reliable protection against biological attack.

It is not to be expected that biological warfare agents would be deliberately chosen to be contagious; that would maximize the risk of spreading disease far beyond the intended target, possibly to the territory of the attacker or his allies. Nevertheless, the unnatural conditions inherent in military operations create the possibility that widespread epidemics would be unintentionally started. There is also the hazard, difficult to evaluate, that the bacteria or viruses used in an attack, or even used in a field test, could subsequently emerge from exposed populations of humans, rodents, birds or other animals with increased persistence, virulence and contagiousness for man.

From this brief account it should be clear that lethal biological weapons would present a devastating threat of killing human populations over large areas. The threat is made particularly formidable by the relative ease with which such weapons could pass into many hands if the technology becomes established and if the customs and attitudes that have generally kept nations from pursuing the development of biological weapons should change. After several years of pursuing a biological weapons program that has not had adequate review or guidance from the Executive Branch, and that has been almost entirely shielded by secrecy from public and congressional knowledge, the U.S. has decided that the best way to minimize the threat of biological weapons is to renounce them altogether. The logical case for doing so rests on the realization that the possession of such weapons would add little, if anything, to our strategic-deterrent capability, whereas their proliferation would present a major threat to the U.S. and indeed to all mankind.

The second category of weapons to be considered is incapacitating biological weapons. An example is Venezuelan equine encephalitis. It is a virus that causes severe headache, nausea and prostration but that has a case fatality rate in natural epidemics of .5 percent or lower. Methods for disseminating incapacitating biological agents and the possibilities for defending against them are essentially the same as those for lethal biological agents. The use of incapacitating biological weapons might be considered in certain unlikely and extreme situations. Perhaps the most "attractive" scenario that has been proposed imagines the entrapment of a large friendly force by enemy troops deployed over an extensive area and intermingled with civilians. In this situation the employment of incapacitating biological weapons in forward and rear areas might impede the enemy advance long enough to allow reinforcement or evacuation of the friendly troops when the alternatives might be to use nuclear weapons or to surrender.

Of course any decision to launch an incapacitating biological attack must face the fact that substantial numbers of civilians, particularly infants and the infirm, will almost inevitably be killed, even if the case fatality rate is only a few tenths of a percent. Beyond that there is the possibility that the fatality rate un-



LOADING PLAN for a CH-47 Chinook helicopter employed for air-dropping the irritating agent CS is depicted as it is shown in a U.S. Army training manual. Each bomb contains 80 pounds of CS-2. Burster tube down the middle of each bomb contains an explosive charge.

der military conditions might be much higher than the rate estimated from natural occurrences of the disease and from various kinds of experimental data. It is also important to note that this scenario assumes the *first* use of biological weapons rather than their employment in retaliation. This adds the additional risk of escalation and enlargement of the conflict that could result from the outbreak of germ warfare of any kind. A principal long-term cost to security of using incapacitating biological weapons, or even of maintaining them, would be stimulation of the proliferation of germ weapons, including lethal ones. The facilities for developing, producing and delivering incapacitating biological weapons are essentially the same as those required for lethal germs. International law and international custom do not distinguish between them.

To summarize, incapacitating biological weapons might seem logical in certain tactical situations, but such situations are most unlikely, and even then the risks would outweigh the possible gain.

Here a more general statement about germ weapons should be made. Such weapons have serious shortcomings from a military viewpoint. Their effects are not as predictable as those of other weapons. They might get out of control. Alternative and already available weapons are preferable, and the acquisition of a biological weapons capability would be an addition to, not a substitute for, preexisting military expenditures and programs.

Military officers and political leaders are strongly disinclined to use biological weapons, partly for practical reasons, partly because of unfamiliarity and partly because of the moral revulsion and apprehension that are undeniably associated with these weapons. There does not currently seem to be any serious interest in biological weapons in high military circles anywhere. Although such weapons could become a terrible menace, the likelihood of this is greatly reduced by the spectacular gesture of renunciation made by the U.S. This is the moment in history when the biological sciences, with their intimate linkage to the lifesaving ethos of medicine, may be spared from being recruited to serve military ends all over the world. Whether or not international biological disarmament can be ensured over the long run may ultimately be related to progress in chemical disarmament, for in the minds of many the two are linked.

Chemical weapons present a much more immediate problem. They were used in World War I and are stockpiled by the U.S. and the U.S.S.R. and are also possessed by several other nations. The distinction between lethal weapons and incapacitating ones has more practical importance here than it has with biological weapons. There are strong restraints against the use of lethal chemical weapons, and until recently nonlethal chemicals have been excluded from warfare as well. From an arms-control point of view there are important arguments for treating lethal and nonlethal chemicals together. Still, for the purpose of analysis it is useful to make the distinction.

Modern lethal chemical weapons employ the nerve gases first developed (but not used) by Germany during World War II. These agents are hundreds of times more poisonous than the poison gases of World War I; they kill when they are inhaled or when they are deposited as liquid droplets on the skin. The term "nerve gas" derives from the fact that these agents operate by interfering with the transmission of nerve impulses across synapses. They do so by inactivating the enzyme cholinesterase, which normally functions to terminate the transmission of a nerve impulse. In the presence of a nerve agent, nerve impulses continue without control, causing a breakdown of respiration and other functions. Death caused by nerve-gas poisoning results from asphyxiation. It is preceded by blurring of vision, intense salivation and convulsions.

The U.S. has stockpiled a variety of tactical nerve-gas weapons, and the U.S.S.R. is believed to have done so too. The weapons include mines, artillery projectiles, rockets, bombs and aircraft spray devices.

The U.S. stockpile includes two kinds of nerve agent. One is GB, a code name for isopropylmethylphosphonofluoridate. It is also known as Sarin and was produced in limited amounts by Germany during World War II. Sarin is a volatile liquid that evaporates at room temperature to a colorless and odorless gas.

Weapons containing Sarin release it as a spray, which then evaporates to create a respiratory hazard for unprotected personnel. The lethal exposure for man is estimated to be approximately 100 milligram-minutes per cubic meter. This means, for example, that a man would accumulate a lethal dose in 10 minutes if the concentration of Sarin in the air were 10 milligrams per cubic meter.

Since the hazard posed by Sarin is mainly respiratory, a gas mask provides good protection. Modern gas masks are capable of reducing the concentration of all known war gases, by a factor of about 100,000. In addition there are chemical antidotes for nerve agents that can provide protection if the dose of agent is not very great and the antidote is administered promptly.

The other kind of nerve agent in the U.S. stockpile is VX. The chemical formula of VX is still secret, although the WHO report suggests that the agent is ethyl S-dimethylaminoethyl methylphosphonothiolate. It is a member of a class of compounds first prepared in the mid-1950's in the course of a search for improved insecticides. (Sarin was also the outcome of insecticide research.) Also a liquid but several times more toxic than Sarin and much less volatile, VX is lethal either when inhaled or deposited on the skin. VX kills in a matter of minutes, and by contaminating the ground and objects on which it is deposited it can make an entire area hazardous for many days. It was VX that killed the sheep in Utah.

The lethal dose of VX applied to the skin has been estimated to be from two to 10 milligrams, depending on the site of application. Since contact with even a small droplet of VX can be fatal, adequate protection requires the wearing of a special suit as well as a gas mask. The wearing of protective suits and masks is extremely cumbersome. They are mechanically awkward, and the buildup of heat is a serious problem. Fighting efficiency would be severely reduced by the wearing of full protective equipment and also by the strict observation of various special precautions necessary for survival in a lethal chemical environment. This kind of complexity in gas warfare was clearly recognized in World War I. In the words of one officer: "The range of problems was infinite. How would the soldier eat, drink, sleep, perform bodily functions, use his weapon, give and receive commands? How would he know when his immediate area was contaminated?"

For tactical use against an enemy without protective equipment, lethal chemicals would be devastating. Against an enemy possessing suits and masks and able to impose the wearing of such gear on one's own troops by the threat of retaliation in kind, lethal chemical weapons would enormously complicate the battlefield without giving either side a major advantage. This argues for not initiating lethal chemical warfare. It also suggests, however, a reason for possessing lethal chemical weapons as a tactical deterrent if the other side is thought to have them. For example, if conventional land warfare should ever break out in Europe, with only one side in possession of lethal chemical munitions, that side might be tempted to use them in order to force opposing troops into protective gear while its own forces, taking advantage of their knowledge of the timing and location of the chemical attack, pressed the offensive. Having this knowledge, the argument goes, their operations would be considerably less complicated. It is this kind of analysis that presumably underlies the U.S. policy of maintaining lethal chemical weapons even though it is our policy never to initiate their use.

Both the plausibility and the accuracy of the foregoing scenario can be challenged. Many would maintain that a major war in Europe is extremely unlikely. It is even more unlikely that such a war could go on for many days without resort to nuclear weapons, in which case chemicals would become unimportant. Finally, it is argued, even in the event of a large nonnuclear war the use of chemicals would be strongly deterred by the risk that using such unconventional weapons to obtain any major advantage would trigger a nuclear response.

Clearly there are some risks in either approach. The second approach, however, would allow the renunciation of the possession of lethal chemical weapons.

Lethal chemical weapons could be produced by nonnuclear nations to provide a capability for strategic attack on urban populations. Under meteorological conditions favorable to the attack, a medium bomber or a converted commercial air transport can deliver enough nerve agent to kill a high proportion of unprotected people throughout the central region of a large city. For example, the WHO report estimates that an airborne attack across the wind along a two-kilometer line, releasing four tons of chemical agent over a city, would cause high casualties over an area of between two and 40 square kilometers, depending on the type of agent and munitions used. Given adequate warning a highly

AGENTS	DISEASES	INCUBATION PERIOD (DAYS)	EFFECT OF TREATMENT	CONTAGIOUSNESS
VIRUSES	EASTERN EQUINE ENCEPHALITIS	5 TO 15	NONE	BY VECTOR
	TICK-BORNE ENCEPHALITIS	7 TO 14	NONE	BY VECTOR
	YELLOW FEVER	3 TO 6	NONE	BY VECTOR
RICKETTSIAE	ROCKY MOUNTAIN SPOTTED FEVER	3 TO 10	GOOD	BY VECTOR
	EPIDEMIC TYPHUS	6 TO 15	GOOD	BY VECTOR
BACTERIA	ANTHRAX	1 TO 5	MODERATE	LOW
	CHOLERA	1 TO 5	GOOD	HIGH
	PNEUMONIC PLAGUE	2 TO 5	MODERATE	HIGH
	TULAREMIA	1 TO 10	GOOD	LOW
	TYPHOID	7 TO 21	GOOD	HIGH

AGENTS	DISEASES	INCUBATION PERIOD (DAYS)	EFFECT OF TREATMENT	CONTAGIOUSNESS
VIRUSES	CHIKUNGUNYA FEVER	2 TO 6	NONE	BY VECTOR
	DENGUE FEVER	5 TO 8	NONE	BY VECTOR
	VENEZUELAN EQUINE ENCEPHALITIS	2 TO 5	NONE	BY VECTOR
RICKETTSIAE	Q FEVER	10 TO 21	GOOD	LOW
BACTERIA	BRUCELLOSIS	7 TO 21	MODERATE	NONE
FUNGI	COCCIDIOIDOMYCOSIS	7 TO 21	POOR	NONE

BIOLOGICAL AGENTS are shown by category and effect; those that could be expected to cause death are at top and agents that might be used to cause incapacitation are at bottom. Contagion "by vector" means transmission by certain species of mosquitoes or other insects.

COMMON NAME	SARIN	VX	MUSTARD	BZ	CS AND CS-2
MILITARY CLASSIFICATION	LETHAL AGENT (NERVE GAS)	LETHAL AGENT (NERVE GAS)	LETHAL AND INCAPACITATING AGENT	INCAPACITATING AGENT (PSYCHO-CHEMICAL)	HARASSING AGENT
PHYSICAL STATE	LIQUID	LIQUID	LIQUID	SOLID	SOLID
FORM AS DISSEMINATED	VAPOR, AEROSOL OR SPRAY	AEROSOL OR SPRAY	SPRAY	AEROSOL OR DUST	AEROSOL OR DUST
DURATION OF CONTAMINATION	HOURS OR DAYS	DAYS OR WEEKS	DAYS OR WEEKS		CS–MINUTES CS-2–WEEKS

CHEMICAL WARFARE AGENTS included in the U.S. stockpile are listed by category and some of their major characteristics. Data were assembled by the World Health Organization for its recent report on the health effects of chemical and biological weapons.

disciplined population could be defended against such an attack by a combination of gas masks, protective shelters and antidote therapy. Although strategic chemical weapons would add nothing significant to the arsenals of the nuclear powers, the proliferation of such weapons among the nonnuclear nations would obviously constitute a serious hazard. Even though it is unlikely that a small nation could deliver a chemical attack over a wide area of a country that has modern air defenses, it would be much easier to penetrate the air space over one or a few coastal cities.

It is also important to consider the possible role of lethal chemical weapons in "low level" conflicts. Today such conflicts are fought with high-explosive and flame weapons, which individually have limited area effect. Although such wars can be exceedingly destructive, they become so only when enormous quantities of weapons are used. (In Vietnam, for example, more than 6,000 tons of ammunition were expended by the U.S. daily in 1968.)

Many of the types of munitions used in limited war, however, could be filled with lethal chemicals. In such a case the "kill area" of lightweight munitions such as mortar shells and rockets could be increased by a factor of as much as 100. Even though combatants could be provided with protective equipment, such weapons would be devastating to military units caught unprepared and to civilians in urban areas. Small military units would begin to acquire strategic capabilities against cities.

It is apparent, therefore, that chemical weapons constitute a menace far beyond their possible tactical employment by the major powers. It is this menace that provides one of the chief arguments for chemical and biological disarmament. A concluding but often overriding restraint on the tactical use of lethal chemicals, particularly when the battlefield is on friendly soil, is that their large-scale employment could cause heavy casualties among undefended civilians in the combat zone and out to considerable distances downwind.

Although U.S. policy now treats toxins in the same way as biological weapons, by renouncing even their possession, the UN report classifies toxins as chemicals because they do not reproduce. Toxins are poisonous substances produced by living organisms including plants, animals and bacteria. Examples are ricin from the castor bean, tetrodotoxin from the globefish and botulin from the bacterium *Clostridium botulinum*. Some toxins, such as botulin, are highly lethal to man; others, such as the staphylococcus enterotoxin (the substance responsible for staphylococcal food poisoning), are usually only temporarily incapacitating.

Even though toxins are not capable of reproduction and therefore cannot cause epidemics, they do induce many of the same symptoms associated with infection by disease organisms. Indeed, the principal pathological symptoms of several bacteriological diseases are thought to be caused by toxins produced within the human body by the living microorganisms. Thus toxin weapons, both in terms of the means of their production and the symptoms they cause, are closely related to the biological ones.

For use as weapons toxins could be dispersed as aerosols in much the same way as biological and chemical weapons. Because toxins are not absorbed effectively through the skin, gas masks would provide protection, as would shelters fitted with special air filters. Protection can also be afforded by prior immunization with specific toxoid. Each toxoid, however, is effective only against a particular kind of toxin, and for some toxins the margin of protection is not enough to be of practical significance.

The chief military argument for having toxins is that, because of their great potency, the weight of toxin munitions needed to cover a given area would be lower than the corresponding requirement for standard chemical munitions. There are several technical reasons to question whether this is so, but even if it were, the saving would not be of very great importance for major military powers with their large logistic capability. An active U.S. toxin weapons program would have run counter to the President's decision to demilitarize and declassify U.S. biological weapons research and production facilities and would have made it impossible for the U.S. to take an unequivocal and convincing stand against the use of disease as a weapon of war.

The first chemical weapons to be employed in World War I were nonlethal. It is reported that some soldiers brought police tear-gas cartridges to the front. Soon both Germany and France began using artillery shells containing tear gas, and thousands of these shells were fired months before the famous German attack at Ypres with chlorine gas released from cylinders. Tear gas and other irritant chemicals continued to be used throughout the war—more than 12,000 tons in all. Even larger quantities of such chemicals were prepared but not employed by the belligerents on both sides in World War II.

Modern incapacitating chemical weapons are of two types, one with effects lasting considerably beyond the period of exposure and one with brief effects. President Nixon's renunciation of the first use of incapacitating chemicals has been applied only to the longer-lasting type. An example of this type is the U.S. agent BZ. This is a psychochemical, the chemical identity of which is still secret, although the WHO report speculates that it belongs to the family known as benzilates. BZ is a solid that can be dispersed as an aerosol to be inhaled by enemy personnel. It affects both physical and mental processes, causing blurred vision, disorientation and confusion. Its incapacitating effects can last for several days.

Although BZ has been standardized as a weapon by the U.S. Army and munitions have been loaded with it, it is not regarded as a very satisfactory incapacitating agent. It can elicit unpredictable and often violent behavior. Men sufficiently motivated to fight may do so more tenaciously under its influence. Furthermore, BZ has serious effects on the body's water-balance and temperature-regulation mechanisms that could lead to death, particularly under hot, dry conditions. Much effort has been devoted, without success, to finding a long-lasting incapacitant without these drawbacks or similar ones.

The principal short-term incapacitant now in military use is CS (orthochlorobenzalmalonitrile). This compound was first synthesized in the U.S. in the 1920's. After World War II it was developed by the British government as a riot-control agent and named after its American discoverers, Ben Corson and Roger Staughton of Middlebury College. When employed for military purposes, it is more accurately described as a harassing agent.

The first CS munitions operated by vaporizing the agent from a pyrotechnic mixture. The CS then condenses to form an aerosol of micron-sized particles. Pyrotechnic CS is used in grenades, rockets, artillery shells and cluster bombs. A newer form is designated CS-2. Used in both bulk-disseminating devices and bursting bombs, it is a powder consisting of micron-sized particles treated with silica gel and silicone compound to improve its flow properties and persistence in the field. CS-2 can be effective in the field for several weeks. It is reintroduced into the air by the wind and the movement of people and vehicles.

The effects of CS depend on the particle size of the aerosol. Particles larger than some 50 microns exert their predominant effect on the eyes, whereas smaller particles are more effective as lung irritants. For military use CS-2 is milled fine enough to achieve the latter effect. Exposure to either form of CS causes intense pain in the eyes and upper respiratory tract, progressing to the deep recesses of the lungs and giving rise to feelings of suffocation and acute anxiety. In humid weather moderately heavy skin exposure can cause severe blistering that requires many days for healing.

If exposure is not excessive, the symptoms usually pass within a few minutes after the exposure ends. The lethal dose for man, as estimated from animal experimentation, is very much higher than that required to cause intense irritation. Nevertheless, heavy or prolonged exposure, such as might be expected in confined spaces or in close proximity to a munition emitting the agent, could cause serious lung damage and death, particularly among infants and the infirm. No long-term aftereffects of moderate exposure to CS have been demonstrated. Although investigations of this possibility are now under way, they have not been completed.

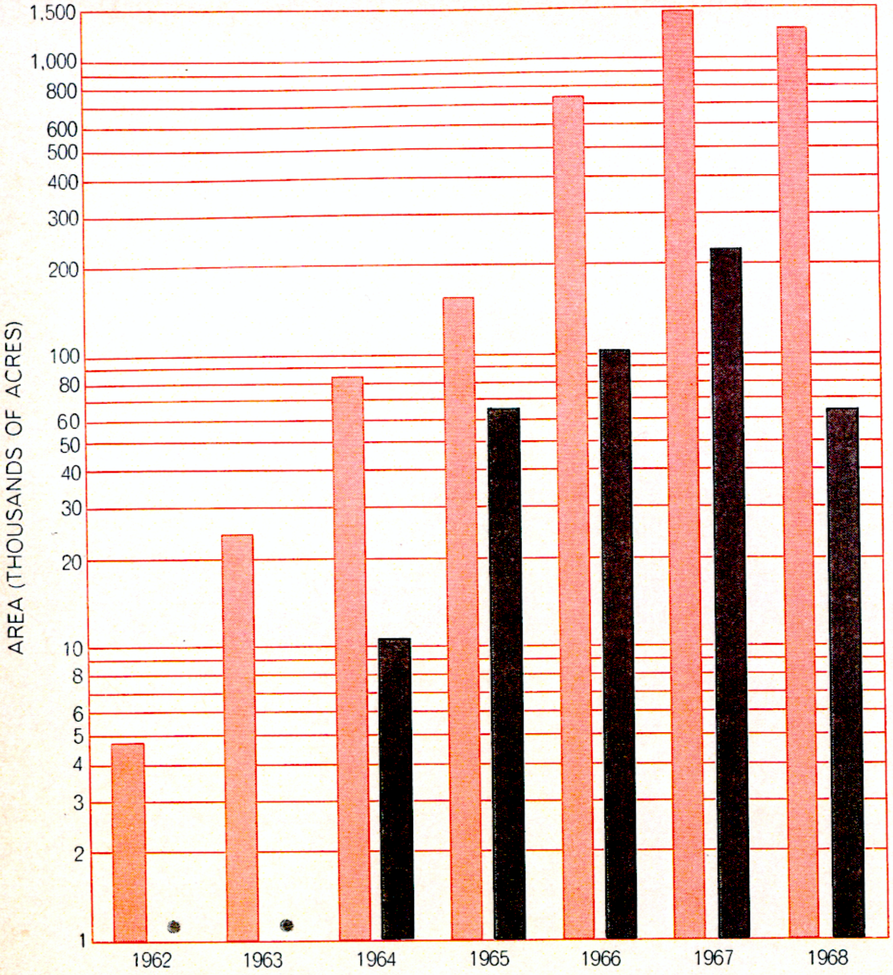
For military purposes CS has supplanted older harassing agents such as ordinary tear gas (CN, or chloracetophenone) and the emetic and respiratory agent known as adamsite or DM.

When used in war against unmasked personnel, harassing agents are effective in forcing an enemy from cover to face capture or hostile fire, to deny him terrain or to upset his fire. Against masked personnel harassing agents are very much less effective, although they reduce fighting efficiency somewhat by forcing men to put on masks. The first major application of harassing gas in combat since World War I has come in Vietnam, where more than 14 million pounds have been used by U.S. forces. At first U.S. policy was to use CS only when its employment would be more humane than the use of more lethal weapons. For example, on March 24, 1965, following the first newspaper reports of U.S. use of nonlethal gas in Vietnam, Secretary of State Dean Rusk made the following statement: "We do not expect that gas will be used in ordinary military operations.... The anticipation is, of course, that these weapons will be used only in those situations involving riot control or situations analogous to riot control."

For five months following Rusk's statement the use of harassing agents in Vietnam ceased completely. Then an event took place that put the use of CS in the most attractive possible light and

AGENTS	TYPE OF WEAPON: NUCLEAR	CHEMICAL	BIOLOGICAL
AREA AFFECTED	UP TO 300 SQUARE KILOMETERS	UP TO 60 SQUARE KILOMETERS	UP TO 100,000 SQUARE KILOMETERS
TIME TO EFFECTIVENESS	SECONDS	MINUTES	DAYS
DAMAGE TO STRUCTURES	WIDESPREAD DESTRUCTION	NONE	NONE
OTHER EFFECTS	PROLONGED RADIOACTIVITY IN AREA OF 2,500 SQUARE KILOMETERS	CONTAMINATION FOR DAYS OR WEEKS	POSSIBLE EPIDEMIC OR NEW FOCI OF DISEASE
NORMAL USE OF AREA	3 TO 6 MONTHS	LIMITED FOR DAYS OR WEEKS	VARIABLE
EFFECT ON MAN	90 PERCENT DEATHS	50 PERCENT DEATHS	50 PERCENT MORBIDITY

THREE WEAPONS are compared for damaging effects. The weapons are a one-megaton nuclear bomb, 15 tons of a chemical nerve agent and 10 tons of a biological agent. In each case the table assumes delivery of weapon by one bomber on an unprotected population.



USE OF HERBICIDES in South Vietnam is stated in terms of Air Force estimates for defoliation (*color*) and crop destruction (*gray*). Dots represent less than 1,000 acres. In South Vietnam some eight million acres are under cultivation and about 14 million are forested.

probably played an important role in bringing about authorization for its renewed employment. On September 5 a Marine officer came on a cave where civilians were thought to be intermingled with Vietcong soldiers. Faced with a choice between sending in an assault force, throwing in CS grenades or abandoning the mission, he decided on CS. It was reported that several enemy soldiers and 400 civilians emerged without injury to noncombatants. Following this incident soldiers and field commanders found a wide variety of uses for CS in regular combat. Soldiers encountered many situations in which it could be used to inflict casualties on the enemy and otherwise perform their mission while reducing their own losses. One of the major uses of CS in Vietnam is to flush enemy soldiers out of bunkers preceding high-explosive fire or infantry assault.

The overall utility of CS in Vietnam is not known, no systematic studies having been made. It has nonetheless been a popular weapon, and under this pressure from the battlefield its use has expanded greatly. One indicator is the yearly record of Army procurement of CS for Southeast Asia, which rose from 253,000 pounds in fiscal year 1965 to 6,063,000 pounds in 1969. Another indicator is the rapid proliferation of experimental and newly standardized CS munitions developed by the Army. As recently as July, 1966, military manuals listed only five types of CS weapons: two grenades and three bulk disseminating devices. Since then 18 new CS munitions have appeared, ranging from grenades with delayed-action fuzes for air drop up to 105-millimeter and 155-millimeter howitzer projectiles, various mortar and rocket munitions and a number of aircraft bombs with area coverage ranging up to a square kilometer.

It is sometimes argued that nonlethal chemical weapons would make war more humane. There is good reason, however, to expect the opposite. As long as lethal weapons are employed in war, if nonlethal chemicals are introduced, it must be expected that they will come to be employed not by themselves but rather in coordination with the weapons already in service, in order to increase the overall effectiveness of military operations. Certainly this has been so in the case of the agent CS.

The expansion of CS use in Vietnam has given rise to two widespread concerns. The first is that the U.S. has departed from its original humanitarian justification for the use of chemicals in war. Second, it is becoming increasingly clear that the long-term arms control cost to the U.S. may be severe. I shall return to this point.

The last category of chemical weapons to be considered here is antiplant agents. These agents were first developed for military purposes during World War II and subsequently came into wide use for weed control. Near the end of the war some consideration was given to using them to destroy rice being cultivated by Japanese soldiers in isolated island strongposts, but the plan was never authorized. Herbicides were used on a small scale to clear roadsides by the British in Malaya during their military operations there in the 1950's.

The use of herbicides in Vietnam was first authorized on an experimental basis in 1961. They next came to be employed there for increasing visibility along roads and waterways and on the perimeters of military installations; then for the destruction of crops thought to be destined for enemy consumption, and finally for the treatment of large areas suspected of harboring enemy base camps or supply routes. By mid-1969 approximately five million acres had been sprayed, 10 percent of it cropland. Following a peak in 1967, anticrop operations were substantially reduced, reflecting adverse criticism of both their propriety and their effectiveness.

Three principal antiplant agents or mixtures have been in service. They are designated Orange, White and Blue. Agent Orange is an equal mixture of the n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The agent is mainly directed against forest vegetation. It is applied undiluted at three gallons per acre, approximately 25 times the average amount for domestic application. Within a week or more after its application the leaves fall from most jungle trees. Orange has been the antiplant agent most widely used in Vietnam, but recently its employment has been suspended because of concern that 2,4,5-T may cause human birth defects.

Agent White is a 4:1 mixture of the triisopropanolamine salts of 2,4-D and 4-amino-3,4,6-trichloropicolinic acid.

The latter component is known as picloram. The agent is sprayed from a water solution at a rate of approximately 7.6 pounds of total herbicide per acre. It is generally used for the same purposes as agent Orange, although its somewhat lower volatility makes it preferable for operations where drifting would be a hazard, as in the vicinity of rubber plantations. The extreme resistance of picloram to biodegradation has been a factor in limiting its employment.

Agent Blue is a water solution of sodium dimethylarsinate, applied at the rate of nine pounds per acre. It is used mainly against rice.

Any evaluation of the military effectiveness of herbicides is made particularly difficult by the fact that they exert their effects on the enemy only indirectly and after a substantial time lag. Certainly the most dubious form of antiplant warfare from a military point of view is crop destruction. It is not generally possible to distinguish crops destined for noncombatants from those to be consumed by soldiers. Indeed, both common sense and the experience of many wars show that when the food supply is restricted, it is the civilians and not the soldiers who go on short rations, and it is the children who are most harmed by malnutrition.

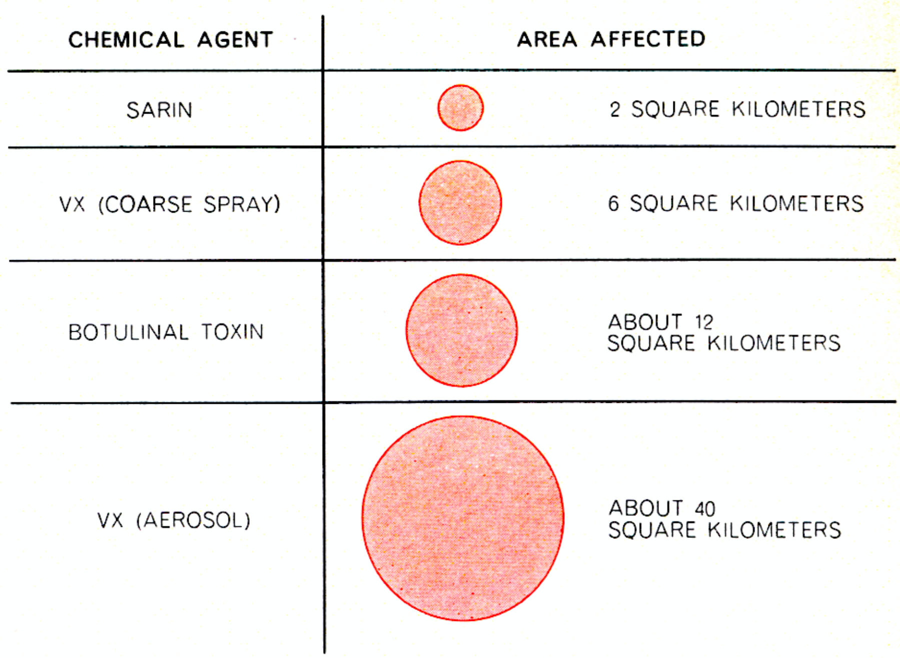
There is very little quantitative information about the overall military utility of herbicides used to improve visibility. There is no doubt that the leaves drop and visibility is thereby improved. As a result an enemy will generally choose to avoid such areas. Nonetheless, an enemy commander will not withdraw his men from action; he will deploy them elsewhere. Thus for every soldier who gains protection from improved visibility there may be another soldier or civilian receiving fire from a redeployed enemy soldier. Obviously the trade-off will not be precisely equal, but this effect will act to exaggerate the apparent military effectiveness of herbicides.

Certainly in some situations there are alternatives to chemical defoliants. In Vietnam giant plows, often working under the protection of military escorts, have been used to clear more than 500,000 acres. Where possible, this method is more effective than the aerial spraying of chemical defoliants because it removes branches and trunks as well as leaves.

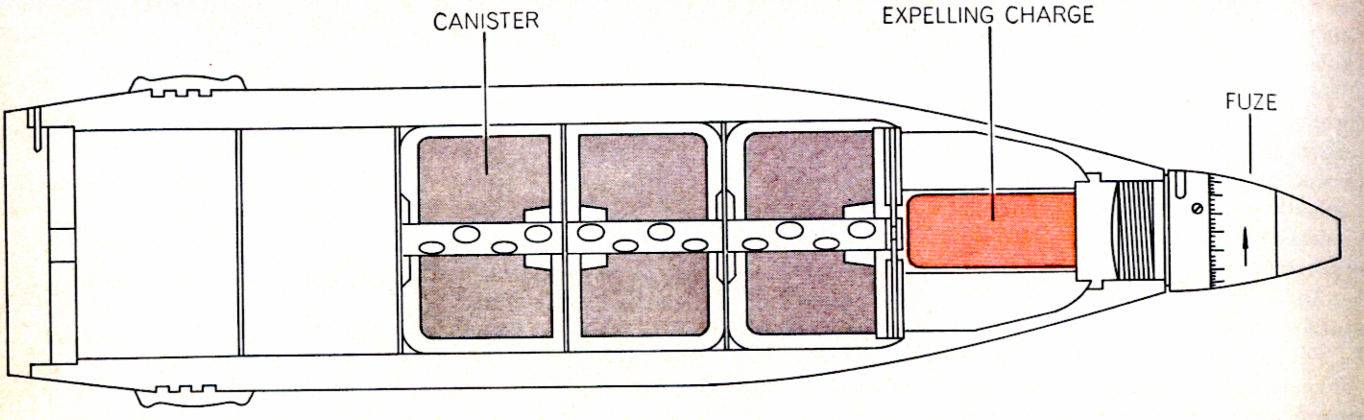
I have attempted to keep the foregoing discussion factual in order to define the issues. Emotions run high on the subject of chemical and biological weapons, however, and few persons can discuss the subject without expressing or evoking strong feelings about whether or not it is wise to use or even to possess such weapons. The strong feelings generated by these weapons have been responsible for the fact that historically they have been singled out for special efforts at arms control. The most important international effort to prohibit the use of such chemical and biological weapons is the Geneva Protocol of 1925. It prohibits (1) "the use in war of asphyxiating, poisonous, or other gases, and of all analogous liquids, materials or devices" and (2) "the use of bacteriological methods of warfare." The protocol does not prohibit research, development, testing or production of gas or germ weapons. It does not prohibit the use of such weapons in reprisal against their first use by the enemy. It does not prohibit the use of riot-control gases or other agents for domestic police purposes. It does not prohibit the use in war of nontoxic smokes used for concealment or of flamethrowers, napalm or other incendiary weapons. The language of the Geneva Protocol is derived from the peace treaties of World War I, which treated gas warfare as already prohibited and specifically forbade the manufacture and importation of war gases by Germany and her wartime allies. On the initiative of the U.S., an article based on the language of the peace treaties was incorporated in the 1922 Washington Treaty on Submarines and Noxious Gases. At the urging of President Harding, Secretary of State Charles Evans Hughes, Senator Elihu Root and a presidentially appointed advisory committee of prominent citizens, the Washington Treaty passed through the Senate with no dissenting votes. Although ratified by the U.S., Great Britain, Italy and Japan, this treaty never came into force because France, whose ratification was required, objected to its provisions on submarines.

The U.S. again pressed for a prohibition against gas warfare at the 1925 Geneva Conference on the Limitation of Arms, proposing language on gas essentially identical with that of the Washington Treaty. The prohibition was extended to cover "bacteriological methods of warfare" at the suggestion of Poland. The resulting treaty—the Geneva Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare—was signed by representatives of 38 nations on June 17, 1925.

The Coolidge Administration and the various supporters of the protocol seem to have assumed that the Senate would give its consent as readily as it had to the Washington Treaty. Almost nothing was done to prepare the case for ratification or to mobilize public support. Meanwhile the Army Chemical Warfare Service, the American Legion, the American Chemical Society and segments of the chemical industry organized the opposition. The arguments



EFFECTS OF ATTACK with chemical agents are charted. The stated effects assume an attack by a single plane, along a two-kilometer crosswind line, laying down four tons of the agent. The use of VX in aerosol form would be to maximize the agent's downwind travel.



ARTILLERY SHELL designed to deliver CS irritant has the agent in canisters that are expelled when the fuze detonates the shell. The shell portrayed, which is for a 155-millimeter weapon with a range of 15 kilometers, is 60 centimeters long, weighs 44 kilograms and carries 4.4 kilograms of CS. In a normal artillery barrage several weapons are fired, delivering a number of shells to target.

made against ratification were that the protocol would be ignored in time of war and that poison gas was more humane than bombs and bullets. The protocol was debated but not acted on by the Senate—apparently because the majority leader did not have the votes. It remained on the Foreign Relations Committee docket until 1947, when President Truman withdrew it together with several other long-pending treaties.

By 1939 the Geneva Protocol had been ratified by 44 nations, including all major European powers. At the outbreak of World War II England, France and Germany exchanged assurances that they would abide by the protocol. In 1943 President Roosevelt declared that gas warfare was "outlawed by the general opinion of civilized mankind" and that "we shall under no circumstances resort to the use of such weapons unless they are first used by our enemies." Japan is believed to have used gas against China before our entry into the war but otherwise gas was not used in World War II. The threat of retaliation provided a sanction. The restraint was reinforced by widespread abhorrence of gas and germs and by military skepticism regarding their utility, but it was the protocol that placed gas and germs in a distinct category and provided a clear standard on which the belligerents could base their conduct.

Since World War II the U.S. has on numerous occasions declared its support for the no-first-use principle of the Geneva Protocol. When President Eisenhower was asked at a press conference if he planned a change in our no-first-use policy, he said: "No official suggestion has been made to me, and so far as my own instinct is concerned, it is not to start such a thing first." During President Johnson's Administration the U.S. supported resolutions passed in 1966 and 1968 by the UN General Assembly, calling for "strict observance by all states of the principles and objectives of the Protocol" and "inviting all nations that have not done so to accede to the Protocol." Some statements, however, have made the U.S. position seem ambiguous. For example, the U.S. Army manual *The Law of Land Warfare*, last issued in the 1950's, states that the Geneva Protocol is "not binding on this country."

A total of 84 nations are now parties to the Geneva Protocol; 16 of them have ratified it since the 1966 UN resolution. The parties include all North Atlantic Treaty Organization members except the U.S., all members of the Warsaw Pact including the U.S.S.R. and all nuclear powers (other than the U.S.), including the People's Republic of China. All major industrial nations except Japan and the U.S. are parties. The protocol has been signed but not ratified by the U.S., Brazil, El Salvador, Japan, Nicaragua and Uruguay.

Whether or not the protocol prohibits the use of harassing agents and antiplant chemicals is a subject of some dispute. On the first occasion when nations were canvassed for their views on the status of tear gas (at a League of Nations Commission in 1930), Canada, China, France, the U.S.S.R. and several other nations agreed with the declared British position that "the use in war of 'other' gases, including lachrymatory gases, was prohibited." None of the nations then party to the protocol made objections to this view. The U.S. delegate, however, expressed hesitation over any commitment to refrain from the use in war of agencies used in peacetime by domestic police and whose use in combat would be "more clearly humane than the use of weapons to which [nations] were formerly obliged to resort." Two years later the League Disarmament Conference unanimously recommended that the use of all gases, including tear gas, be prohibited in war. This view was accepted by the U.S. with the understanding that it did not apply to the use of tear gas for police purposes. The discussions were not directed at the Geneva Protocol but at devising a comprehensive disarmament treaty, an attempt that was disrupted by the approach of World War II. The question did not come up again until 1965, when questions were first raised about our employment of CS and herbicides in Vietnam.

Responding to these questions in 1966, the U.S. representative to the General Assembly stated that the protocol does not prohibit "the use in combat against an enemy, for humanitarian purposes, of agents that Governments around the world commonly use to control riots by their own people" or of chemicals used to control "unwanted vegetation" for agricultural and other peaceful purposes. At the time these views were contested mainly by the U.S.S.R. and its allies. As the scale of chemical operations in Vietnam has increased, however, the U.S. position has come under mounting attack. Last summer Secretary General U Thant urged the members of the UN to "make clear affirmation" that the protocol prohibits the use of all chemical agents, including tear gas, in warfare. Last winter India, Mexico, Pakistan, Sweden and 17 other nations proposed in the General Assembly a resolution holding that the Geneva Protocol prohibits the use in war of all chemical agents directed at men, animals or plants. The resolution was passed by a vote of 80 to three, with 36 abstentions. Portugal, Australia and the U.S. voted against the resolution.

Since then the British government has declared that CS is exempt from the Geneva Protocol, although Britain still considers the tear gases known in 1930 to be prohibited. The British argument was that CS is less toxic than older tear gases, but it is generally thought that the real motivation of the cabinet was to avoid risking charges that the use of CS for riot control in Ulster was illegal. If so, this reflects a confusion regarding the meaning of the Geneva Protocol, which by its terms prohibits the use of gas only in warfare. The distinction between the use of tear gas for domestic police purposes and the prohibition of its use in war has been observed without difficulty by many nations ever since World War II. Even Sweden, a nation that has led the opposition to the use of tear gas in war, uses it in riot control at home. Ironically, it may be that the massive use of CS in war and the excesses this breeds will generate serious opposition to its domestic use.

As the U.S. moves to ratify the Geneva Protocol, the Administration must decide on a policy regarding the use of harassing agents and herbicides. There is no great difficulty in identifying the pros and cons of maintaining an option to use these agents in war. The difficulty arises when one attempts to quantify the various arguments and then to place values on them in order to reach conclusions.

The principal gain to the user of these agents in war is that to some extent they enable him to increase enemy casualties and to reduce his own. These agents, however, are of significant effect almost only in counterguerilla warfare and, in the case of CS, only if opposing troops are unprotected by gas masks. Hence the arguments for keeping these weapons become important to the extent that a nation anticipates involvement in such wars. CS can be expected to lose its advantage in any case, for once the impression is created that one's forces will use gas, supplies of masks will become much more available throughout the world. North Vietnamese troops in South Vietnam are now largely equipped with fairly good Chinese Communist gas masks, and increasing numbers of the excellent Russian Shlem masks are appearing. Even for guerillas the expense of masks is not great.

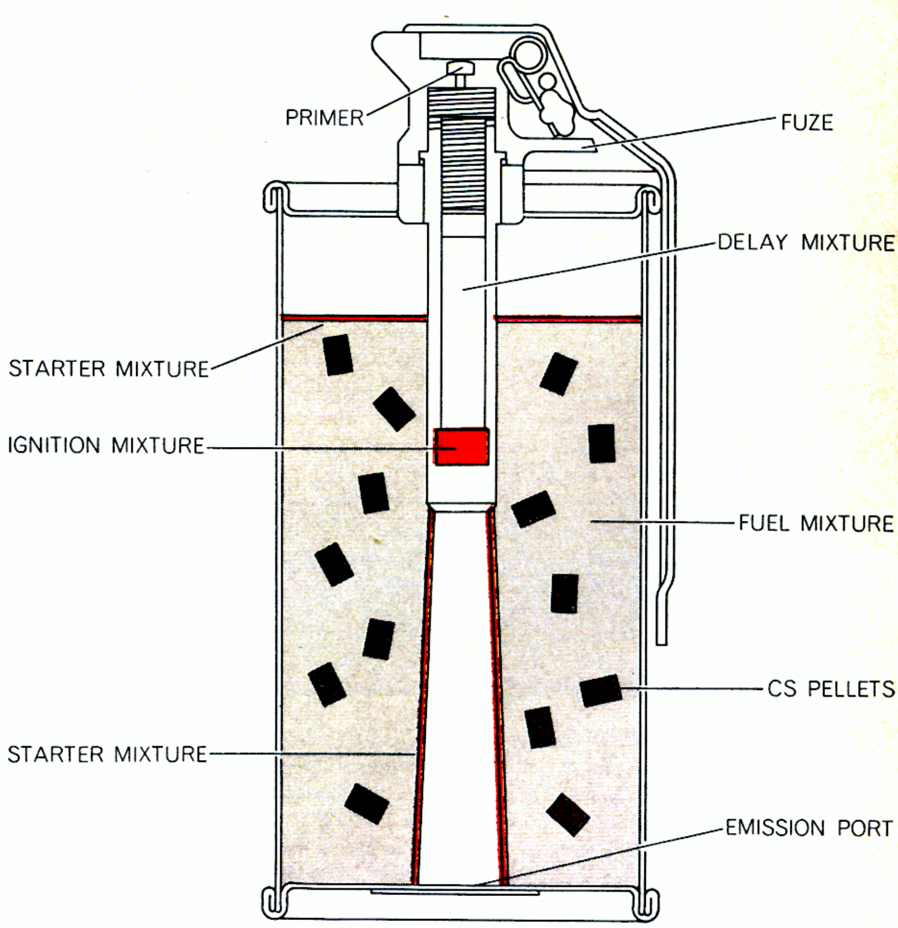
The main threat to security of continuing the use of these agents is the increased likelihood of proliferation of chemical weapons and of the breakdown of the restraints against chemical warfare. Our employment of harassing gas in war, particularly when it is done on a large scale in conjunction with ordinary military operations, stimulates military planners in other nations to secure gas masks, initiate chemical training and upgrade chemical cadres and to consider acquiring for their own nations chemical weapons of various types, including lethal ones.

The large-scale military employment of antiplant chemicals poses ecological and public health problems of which we still know little but that could be most serious in the long run. The precedent of countenancing large-scale alteration of the environment in the conduct of war has obvious perils. Moreover, in many parts of the world use might be made of chemicals as agents of starvation and economic warfare against the civil population. Because of the relative ease with which this tactic can be practiced, it would be difficult to stop once the precedent is set.

The general problem of preventing chemical and biological warfare is to a large extent a psychological one. Perhaps the central problem is to prevent the application of biochemistry and biology to the opening up of a new and highly unpredictable dimension of warfare. If we can maintain and reinforce the traditional expectation that no gas or germs will be used in war, there will not be much pressure for these weapons to proliferate.

This psychological aspect of the problem has been understood by essentially all nations, including the U.S., ever since World War I. Recently, however, a dangerous break with tradition has been allowed to occur and to escalate in Vietnam. Many who have studied the problem consider the use of chemical weapons there, even though they are not lethal chemicals, to be the major and most immediate threat to the barriers that prevent chemical warfare.

If we can accept the loss of our option to use harassing agents and antiplant chemicals as weapons of war, then, judging from the recent vote in the General Assembly, it appears likely that all important nations of the world could be brought to agree. If, on the other hand, the long-observed rule of "No chemical and biological weapons" is abandoned, there will be no unique and equally simple standard on which national practice and international agreement can be based.



CS GRENADE with a 12-second delay fuze is designed to be delivered either by a grenade launcher or by airdrop. One of these grenades weighs one pound and holds 115 grams of CS.