Chemical and Biological Warfare

Should Defenses Be Researched and Deployed?

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The threat of chemical and biological weapons of mass destruction has intensified because of improved delivery systems and advances in chemistry, genetics, and other sciences. Possible US responses to this threat include deterrence, defenses, and/or disarmament, including a reaffirmation of the Biological and Toxin Weapons Convention of 1972, which is now in jeopardy. This article discusses the history of chemical and biological warfare, existing and potential weapons, the proliferation of weapons and delivery systems, ways to prevent the use of these weapons, and ways to protect populations from their effects.

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The noise of fourteen thousand aeroplanes advancing in open order. But in the Kurfurstendamm . . . , the explosion of anthrax bombs is hardly louder than the popping of a paper bag

Aldous Huxley, *Brave New World*, 1932

IN THE nuclear age, another type of weapon of mass destruction is often forgotten; yet, the stockpile of nerve gas in the United States alone is said to be "sufficient to kill the entire population of the world 4000 times over,"[1] given an efficient delivery system. Chemical and biological weapons may be the ultimate "capitalist weapon," leaving the economic infrastructure intact to an even greater extent than the neutron bomb.

See also pp 675 and 677.

HISTORY

However unthinkable the use of these horrific weapons, there is ample historical precedent. In 1347, the Tatars, afflicted by bubonic plague during their siege of Caffa, used catapults to hurl their dead into the city, spreading the disease to Genoese defenders, who took the "black death" with them when they fled to Italy In colonial days, the British gave American Indians "gifts" of smallpox-carrying blankets.[2] In World War I, at least 1.3 million men were wounded by gas (including Adolf Hitler), and 91 000 of them died.[1] In the 1930s, the Italian army repeatedly gassed Ethiopians, and Japan launched more than 800 gas attacks in its conquest of Manchuria, China (*The Wall Street Journal*. September 15, 1988; sect 1:1, 26). The Japanese also may have used biological agents to attack the Chinese and are believed to have conducted experiments with the agents in thousands of Chinese prisoners of war.[1] Many other examples could be cited

In World War II, the use of chemical and biological weapons could have been far more extensive than it actually was. The Germans had developed tabun and sarin, extremely potent cholinesterase inhibitors, and German factories were capable of producing approximately 11 000 tonnes of poison gas per month. The *Luftwaffe* had a half million gas bombs. Although lagging in research on nerve gas, the British biological warfare project was years ahead of the Nazis'. The British actually produced 5 million cattle cakes filled with anthrax, and the United States had a contingency plan to use the anthrax bomb against Germany.[1]

EXISTING AND POTENTIAL WEAPONS

The United States stockpiled approximately 36 000 tonnes of chemical warfare agents[3] before production ceased around 1969. The agents include phosgene, hydrogen cyanide, and mustard gas.[4] Approximately half the inventory is nerve gas.[5] Because of chemical deterioration, only approximately 10% of the stockpile has immediate military utility, and an additional 10% to 20% has limited utility, according to the Department of Defense.[5] Currently, the United States is reducing the stockpile of unitary chemical weapons.[6] However, the United States continues to produce binary chemical weapons, which contain two components that form a lethal agent when mixed.[7,8] The Soviets are believed to have stockpiled 270 000 to 360 000 tonnes of a variety of chemical weapons, including phosgene, nerve agents (tabun, sarin, and soman), hydrogen cyanide, and blistering agents (mustard gas).[9] At The Paris Conference on Chemical Weapons in January 1989, the Soviet Union announced that it would destroy its stockpile,[10] which it declares consists of 45 000 tonnes of toxic substances.[11]

Numerous pathogenic organisms, including bacteria, rickettsiae, viruses, and fungi, have been proposed and probably investigated as agents of bio-

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logical warfare.[12-15] Many of the organisms are highly lethal, although others (such as brucellosis, developed as a potential weapon by the United States during World War II)[1] might be used with the intention of simply incapacitating the enemy for long periods. Smallpox virus has been called the most important agent,[12] possibly because there is an effective vaccine as well as a somewhat useful (but generally unavailable) antiviral drug, methisazone. Conceivably, a nation might protect its own population, then unleash the virus against an unvaccinated world. (Although widely believed to be extinct, samples of the virus are still kept in maximum-security reference repositories, under the auspices of the World Health Organization, in Atlanta, Ga, and Moscow.)[16]

Instead of the organisms themselves, their toxins might be used. Although toxins could not start epidemics, they might survive transport better. A number of toxins, including botulinus toxin, have been studied by the US Department of Defense. Trichothecenes, derived from the mold fusaria and allegedly found in a few samples related to "yellow rain" attacks, are believed to be produced at Berdsk Chemical Works near the Soviet city of Novosibirsk, a facility suspected of involvement in chemical and biological warfare. At least 22 articles in the Soviet literature concern the optimum conditions for biosynthesis of this agent in large quantities.[17]

Advancements in biotechnology open prospects for the development of organisms that are resistant to existing drugs and vaccines or that produce more lethal toxins, possibly by modifying normally harmless or relatively benign microorganisms.[18] The Soviets have recognized this possibility for at least two decades. The incorporation of the genetic code for a component of cobra venom into viruses such as influenza virus is one of the ominous possibilities suggested in a series of articles in the *The Wall Street Journal* (April 27, 1984:26). Cobra venom is composed of more than 20 protein components, such as cobrotoxin, a potent neurotoxin that binds to the acetylcholine receptor. The role for such weapons was discussed during a Warsaw Pact scientific conference in East Germany in 1971, where it was reported that[5]:

> the rapid development of biological engineering will make it possible in just a few years to produce synthetic or partially synthetic toxins on a large scale. Such toxin agents represent a combination of the hitherto chemical and biological weapons. . . .
>
> Neurotropic toxins are toxic proteins which are primarily byproducts of the life cycles of microorganisms. The neurotropic toxins are the most toxic chemical substances. . . . Under combat conditions, they can be used as an aerosol or in solid or liquid state in mixed elements of ammunition, they can also be used for sabotage purposes.

DELIVERY MECHANISMS

The effectiveness of aerosols for dispersing biological weapons has been demonstrated in the Soviet literature as well as more than 200 experiments in the United States. In 1950, US Navy vessels released clouds of *Bacillus globigii* and *Serratia marcescens* over San Francisco, Calif. Nearly everyone in the city inhaled 5000 or more particles contaminated with bacteria. In 1966, the Chemical Corps Special Operations Division released aerosols of bacteria (believed to be harmless) in the New York City subway. Because of the turbulence generated by the trains, bacteria were carried to the ends of the tunnels within minutes.[1] These methods could easily be employed by terrorists.

Many types of delivery mechanisms are feasible: missiles, artillery, mines, multiple-rail and tube-launched rockets, fighter-bombers, and attack helicopters.[15-19] Intercontinental delivery of chemical and biological agents is now possible with ballistic missiles. Some investigation has been carried out in the Soviet Union into the effects of warhead "tumbling" as a means of dissemination of chemical agents from large missiles.[15]

Cruise missiles might be the ideal delivery system for biological weapons because of their ability to place a toxic cloud close to the ground. Flight at subsonic speeds would avoid some of the problems of heating the agent when it is ejected into the wind stream. The combination of the cruise missile and existing lethal organisms would be vastly superior to the blast effect of nuclear weapons and would rival nuclear weapons fallout in terms of area coverage per tonne of payload.[20] The calculations that led to this conclusion are based on atmospheric tests of nuclear weapons, experiments in the dispersal of nonlethal agents from aircraft and the lethal dose of various biological agents, and assumptions about meteorological conditions. In the BRAVO test explosion at Bikini Atoll, Marshall Islands (yield, 12.7 to 13.6 megatonnes), the lethal fallout contour (3 Gy in 96 hours) covered an area of approximately 26 000 km^2.[2(p+37)] Given suitable weather conditions and a cruise missile that flies like a crop duster, 100 g of a biological agent (approximately 10^{10} lethal doses of anthrax spores) could cover approximately 2.6 km^2 under light wind conditions at night, and 0.9 tonnes could cover approximately 26 000 km^2—an area the same order of magnitude as the lethal fallout from a ground-burst nuclear warhead that weighs more than 0.9 tonnes (a warhead that weighs 0.9 tonnes has a yield of approximately 0.9 megatonnes).

PROLIFERATION

The recent furor over the Libyan complex near Rabta, which is potentially capable of producing tens of tonnes of toxic substances daily, has called attention to the "poor man's atomic bomb." The US Defense Intelligence Agency believes that approximately 20 other nations (in addition to the United States, the Soviet Union, and France) now possess chemical weapons (*The Wall Street Journal*. September 15, 1988;sect 1:1, 26). Many other Third World nations have chemical warfare capability. Iraq is said to have produced several thousand tonnes of mustard gas, tabun, and sarin since the early 1980s.[22] In addition, 10 nations are believed to be developing biological weapons (*The Wall Street Journal*. September 19, 1988;sect 1:1, 23). The appeal of such weapons to Third World nations is obvious. Sophisticated technology is not required, and the weapons are very cost-effective. For a large-scale operation against a civilian population, casualties might cost $2000 per square kilometer with conventional weapons, $800 per square kilometer with nuclear weapons, $600 per square kilometer with nerve gas, and $1 per square kilometer with biological weapons.[23]

Long-range delivery systems are also proliferating. Aging, "obsolete" ballistic missiles cast off by the superpowers are being acquired by Third World nations. The range of the missiles is extended if they carry a lighter, chemical or biological warhead, and inaccuracy is a lesser problem. The Soviet SCUD missile is believed to be in the hands of Iran, Iraq, North Korea, Libya, Syria, and several other nations. The US Nike-Hercules missile has been modified by South Korea, and Argentina, China, and Brazil are marketing new missiles (*The Wall Street Journal*. September 15, 1988,sect 1:1, 26).

DISADVANTAGES OF CHEMICAL AND BIOLOGICAL WEAPONS

While chemical and biological weapons can terrorize their victims with ghastly effectiveness, they also pose problems for the user. Invading troops would have to operate in a contaminated environment. Biological weapons might outwit their creators' precautions for protecting their own population as living organisms can develop resistance to vaccines or antibiotics. Accidents at

production facilities could threaten enormous numbers of people.

The persistent ecological consequences of producing and testing chemical (and especially biological) agents are potentially more harmful and certainly less well understood than the radiological effects of nuclear weapons tests.[24] The myxomatosis inoculation of a few rabbits in France in 1952 resulted in the spread of disease over an entire continent.[25] At the scene of British World War II tests of anthrax bombs on the island of Gruinard, a 1979 survey still detected viable spores,[26] despite an effort at decontamination by burning off the heather.[1] By 1983, the area of significant contamination was small enough to make effective decontamination feasible using sporicides such as potassium permanganate, formaldehyde, glutaraldehyde, and peracetic acid, although such agents might also raise ecological concerns.[27]

METHODS FOR PREVENTING THE USE OF CHEMICAL AND BIOLOGICAL WEAPONS

There has always been a particular revulsion against chemical and biological weapons. In 1925, the Geneva Protocol was established to forbid the *first* use of these weapons. As of 1986, the protocol has been signed by 108 nations.[18] While this protocol prohibits the use of these weapons, it does not prohibit production or stockpiling. Despite this protocol, there have been at least 40 allegations (many not verifiable) of chemical and biological weapons use between 1969 and 1986.[13]

Production and research into the use and effects of these weapons continue. Those who argue for expanded US investment in research on these weapons can cite deterrence as the rationale. Since World War I, the victims of chemical agents have been nations that had no capacity to retaliate in kind.[5,20]

A variety of circumstances may have prevented Hitler from using his secret weapons (tabun and sarin) against the Allies, although nothing prevented him from testing them on inmates of concentration camps.[1] It is possible that Hitler hesitated because of his belief, based on extremely flimsy evidence, that the British also possessed these weapons. Retaliation would not only have killed many German civilians, but might have incapacitated the Wehrmacht's transportation system, which was heavily dependent on horses. (Late in the war, Hitler might have used poison gas despite the risk of retaliation, but by then he lacked an air force to deliver it.)

One might infer that in-kind deterrence is part of Soviet doctrine based on their extensive capacity to engage in chemical—and possibly biological—warfare. At the end of World War II, German attempts to destroy their own chemical warfare plants failed, and the Soviets acquired whole factories along with technical information.[1] The US Defense Intelligence Agency reported that the Soviet production, testing, and storage facilities were continuing to expand as of 1985. At that time, more than 45 000 troops that specialized in chemical warfare served in the ground forces alone.[19] Another report claims that up to 2000 scientists and technicians are employed by the Institute of Molecular Biology near Novosibirsk, the largest of three research and development institutes believed to be concerned with biological warfare.[9]

The existence of defenses against chemical and biological weapons might also be considered a part of deterrence (by preventing an enemy from achieving his objective) or alternately as evidence of intentions to use such agents. It is possible that the British manufacture of 40 million gas masks in 1939[28] might have helped discourage Hitler from launching a gas attack. In addition, allied military leaders arranged to inoculate approximately 100 000 soldiers against botulism, hoping to convince the Germans that the Allies were prepared for biological retaliation; the Germans never called the bluff.[28]

Many western scientists argue against deterrence or defenses and in favor of relying solely on international agreements to ban chemical and biological weapons. (Such scientists generally seem to see deterrence or defense and arms control as mutually exclusive, although proponents of the former do not necessarily oppose arms agreements *in addition* to defense.) To date, there has been better success in obtaining agreements to limit chemical and biological agents than to limit nuclear weapons. The US generals were never able to answer a question posed by Matthew Meselson in the 1960s: under what circumstances would they actually order the use of biological weapons? Because the effects of biological weapons are so unpredictable, any available alternative would be used instead. Even for retaliation against a massive and deliberate biological attack, "the alternative of nuclear weapons was available and would be preferred."[35] Convinced by this argument, President Richard Nixon ordered unilateral disarmament of biological weapons in 1969: the abandonment of development programs for biological weapons and the destruction of weapons stockpiles.

In 1972, the Biological and Toxin Weapons Convention was established to supplement the Geneva Protocol and since then has been signed by 103 nations, including the United States and the Soviet Union. Unlike the Geneva Protocol, this convention prohibits the development, production, and stockpiling of biological and toxin weapons. However, the Convention does not outlaw research into defenses against biological weapons. Recent increases in spending for such research ($60 million in 1988 [*The Wall Street Journal*. September 19, 1988;sect 1:1, 23]) have been opposed by scientists.[31] More than 800 scientists have signed a pledge not to do work that could help develop biological weapons. Many believe this includes the development of vaccines against such weapons because "offensive and defensive research are indistinguishable" (*The Wall Street Journal*. September 19, 1988;sect 1:1, 23.) It is also argued that there is no feasible defense against biological weapons, given the vast number of possible agents (unless the agent to be used is known), but that attempts to develop a specific defense would make it possible to use that specific agent offensively, thus making the use of the weapons less unthinkable (*The Wall Street Journal*. September 19, 1988;sect 1:1, 23).

A ban on the use of existing vaccines has also been proposed: "negotiating an end to the vaccination of troops [by the United States and the Soviet Union], with its reassuring implications for reduced biological warfare risk, would be a final step in ending the fear of smallpox."[32] In this view, vulnerability to a weapon seems to be a prerequisite for assuring compliance with a ban against its use.

Confidence in the Biological and Toxin Weapons Convention has been shaken by accusations of treaty violations. While there have been many allegations of chemical and biological weapons use, including claims that the United States used biological agents in Cuba and North Korea, the two allegations of greatest threat to US confidence in the convention are (1) the alleged use of mycotoxins in Southeast Asia and (2) an incident in the Soviet city of Sverdlovsk.

The US claims of Soviet use of the chemical toxin trichothecenes, or yellow rain, in Southeast Asia have been criticized by many scientists who have been persuaded by the bee feces explanation for the yellow substance.[5,18,33] This hypothesis was formulated by Matthew Meselson, the man who is credited with fathering the treaty that might be destroyed by proof of Soviet use of mycotoxins.[30] Others, citing inadequacies

in the investigations, have an equally strong conviction that toxin weapons were used in Southeast Asia.[34] However, incontrovertible evidence was not adduced to support this conviction.

The Sverdlovsk incident continues to be a subject of heated controversy. The report of an anthrax outbreak caused by an explosion at a Soviet biological weapons factory in Sverdlovsk apparently originated in *Posev*, an obscure magazine, based in Frankfurt, East Germany, published by Soviet émigrés.[1] The Soviet news agency Tass admitted that there had been outbreaks of anthrax in Sverdlovsk, but attributed them to contaminated meat. The US intelligence analysts claimed that cases of inhalational anthrax had occurred, that aerial decontamination attempts were consistent with an accident at the military facility, and that the 1000 or more cases exceeded the annual incidence of anthrax throughout the Soviet Union by at least a factor of 100.[18] Soviet officials countered that there had been no cases spread by inhalation, no aerial decontamination, and only 96 cases of illness.[35,36] (Earlier, a Soviet official had stated that decontamination had been necessary because some "undisciplined workers" had thrown contaminated meat into open garbage containers.[37]) Their explanations persuaded a group organized and led by Matthew Meselson, whose requests to meet with Soviet scientists were granted under President Gorbachev's *glasnost*,[38] but the Pentagon remains unconvinced.[35]

While some persons, alarmed by reports of alleged biological warfare activities as well as by the proliferation of the weapons, call for improvements in intelligence and in response capabilities,[23] others consider these recommendations an "irresponsible provocation" that might weaken prospects to "stave off a biological arms race."[39] Proponents of the latter view believe that we must restore confidence in the existing legal regimes of prohibition and that the main burden for doing so resides in Washington, DC, not Moscow. In this view, the best hope for preventing the use of biological weapons is a ban on research into medical defense against biological war, except for investigations of "passive defenses" (clothing and vehicles impervious to chemical and biological agents) that do not involve actual testing with pathogenic organisms or toxic chemicals.[13,39]

The lack of verification provisions in previous treaties has been noted.[13] Possible verification strategies have been extensively discussed,[14] along with the difficulties that result from the relative ease of production of chemical and biological weapons by using technology that has many legitimate applications such as the manufacture of fertilizer, pesticides, and pharmaceuticals.[5] Beyond verification, assuring compliance may be the key issue.[34]

CIVIL DEFENSE IN CASE OF ACTUAL USE OF CHEMICAL AND BIOLOGICAL AGENTS

Because the 1972 treaty as well as current initiatives to restrict chemical weapons may fail to prevent use of such agents, some nations currently deploy defenses. These nations may still recall the failure of the Geneva Protocol of 1925.[29]

The Soviet corps of chemical warfare specialists has approximately 30 000 vehicles for decontamination and reconnaissance and has developed more than 200 areas for teaching all forces how to protect themselves and how to clean up the area following combat in which chemical weapons have been used. The training includes the use of actual chemical agents.[19] Soviet civil defense textbooks used in institutions of higher education instruct citizens in how to recognize a chemical or biological attack and in protective measures.[40-42] Gas masks are shown as part of standard equipment for shelters. Filmstrips for required civil defense classes show detailed instructions for the decontamination of areas affected by various agents (including mustard gas and sarin) with solutions of hypochlorite, lime, sodium hydroxide, or ammonia.[43] Specifications for ventilating systems in Soviet blast shelters include provision for operation in "filter-ventilation" or "total isolation" mode to protect against radioactive fallout, chemical agents, or toxic gases from combustion. The exhaust blast valves are designed to maintain a small positive pressure to prevent unfiltered air from entering.[44]

In contrast, specific training in chemical warfare defense is not given to citizens or even to civil defense organizations or fire and police personnel within nations in the North Atlantic Treaty Organization. Apart from Switzerland and Sweden, no nation outside the Warsaw Pact has any detection or alarm provision for the civilian population.[9] (Swiss blast and radiation shelters are also equipped with absolute filters to remove chemical and biological agents.[45,46]) Currently, detectors of aerosols that might carry biological agents are only in the developmental stage.[20] However, several possible detection methods seem promising.[14]

With regard to biological weapons, Soviet inattention to public health (as illustrated by the fact that anthrax is endemic in the Soviet Union, irrespective of the cause of the Sverdlovsk outbreak) can be said to constitute a "window of vulnerability." An efficient network of disease control centers has been proposed by Press[2] as a "minimal defensive necessity."

In addition to the passive defenses discussed previously, active defenses might also be deployed against the delivery systems. Some argue that strategic defenses such as those designed for use against nuclear-armed intercontinental ballistic missiles[47] would work equally well against missiles armed with other types of warheads. In this view, such defenses would be more effective against a few missiles launched by a Third World power than against a massive attack by a superpower. A substantially less expensive technology—the "Brilliant Pebbles" concept—has recently been proposed with a cost estimate of $10 billion.[48]

While some have argued that strategic defenses would be ineffective against cruise missiles, which are better carriers for biological weapons, these subsonic projectiles are actually targeted more easily than intercontinental ballistic missiles. Soviet SA-10 surface-to-air missiles and Foxhound fighter airplanes with look-down, shoot-down radar can already destroy US cruise missiles.[49]

COMMENT

Chemical and biological weapons exist and are proliferating. There is considerable precedent for their use. It is clearly in the interest of humankind to prevent the future use of such agents of mass destruction, particularly as they become ever more lethal with advances in bioengineering.

As with nuclear weapons, the argument regarding the best preventive strategy often pits deterrence and defense against disarmament treaties. In actual practice, the Soviet Union has a substantial investment in the former, although it does sign treaties. Western nations (except Switzerland in the realm of defense only) have a much more limited investment in the development and production of weapons or protective measures.

Difficulties in verifying (or enforcing) treaties are illustrated by alleged treaty violations. These same difficulties apply to all nations that possess or aspire to possess these weapons. Irrespective of treaties that concern weapons production, serious discussion is needed regarding improvements in the means of protecting the civilian population, as well as troops, against this growing threat.

References

1. Harris R, Paxman J *A Higher Form of Killing: The Secret Story of Gas and Germ Warfare* London, England: Chatto & Windus Ltd; 1982.
2. Press N Haber's choice, Hobson's choice, and biological warfare *Perspect Biol Med.* 1985;29.92-108.
3. Chemical and bacteriological weapons in the 1980s. *Lancet.* 1984;2:141-143.
4. Bleyer H, Stremmel D. Stand und Entwicklungstendenzen bei chemischen Kampfstoffen der imperialistischen Länder. *Z Gesamte Inn Med* 1985;40:40-44.
5. Roberts B. Chemical weapons. a policy overview *Issues Sci Technol.* 1986;2(3):102-115.
6. Carnes SA. Watson AP. Disposing of the US chemical weapons stockpile· an approaching reality. *JAMA.* 1989,262·653-659
7. Budiansky S. Qualified approval for binary chemical weapons *Science* 1986;234:930-932.
8. Burck G. Will Bush be a chemical president? *FAS Public Interest Rep.* January 1989;42:6-7
9. Le Chêne E. *Chemical and Biological Warfare—Threat of the Future.* Toronto, Canada: Mackenzie Institute; 1989.
10. Herby P. The Paris Conference on Chemical Weapons. *Chem Weapons Convention Bull.* February 1989:12-13.
11. Dickson D. Hopes recede for early ban on chemical arms. *Science.* 1988;240:22-23.
12. Koch H. Schädigungen durch biologische Kampfmittel. *Z Gesamte Inn Med.* 1985;40.48-51.
13. Piller C, Yamamoto KR. *Gene Wars: Military Control Over the New Genetic Technologies* New York, NY: Beech Tree Books (William Morrow); 1988.
14. Stockholm International Peace Research Institute. *The Problem of Chemical and Biological Warfare, Vol VI· Technical Aspects of Early Warning and Verification* Atlantic Highlands, NJ· Humanities Press; 1975.
15. Hemsley J *The Soviet Biochemical Threat to NATO.* London, England: Macmillan Publishers Ltd; 1987.
16. Goodwin L. Beating the plague. *Nature.* 1988;332:755
17. Haig AM Jr. *Chemical Warfare in Southeast Asia and Afghanistan* Washington, DC: Library of Congress Congressional Research Service, 1982. Special report 98.
18. *Soviet Biological Warfare Threat.* Washington, DC: US Defense Intelligence Agency; 1986. Publication DST-1610F-057-86.
19. Directorate for Scientific and Technical Intelligence *Soviet Chemical Weapons Threat* Washington, DC: US Defense Intelligence Agency; 1985 Publication DST-1620F-051-85.
20. Chester CV, Zimmerman GP. Civil defense implications of biological weapons—1984. *J Civil Defense.* December 1984,17:6-12.
21. Glasstone S, Dolan PJ. *The Effects of Nuclear Weapons.* Washington, DC. Dept of Defense and Energy Research and Development Administration; 1977.
22. Norman C CIA details chemical weapons spread. *Science* 1989:243:888.
23. Douglass JD Jr, Livingstone NC. *America the Vulnerable The Threat of Chemical and Biological Warfare.* Lexington, Mass: Lexington Books, 1987.
24. Robison WL Radiological dose assessments of atolls in the northern Marshall Islands. In: *Proceedings of the Nineteenth Annual Meeting of the National Council on Radiation Protection and Measurements: Environmental Radioactivity.* Bethesda, Md: National Council on Radiation Protection and Measurements; 1983 40-82.
25. Stockholm International Peace Research Institute. *The Problem of Chemical and Biological Warfare, Vol V· The Prevention of CBW.* New York, NY. Humanities Press, 1971.
26. Manchee RJ, Broster MG, Melling J, Henstridge RM, Stagg AJ. *Bacillus anthracis* on Gruinard Island. *Nature.* 1981;294:254-255.
27. Manchee RJ, Broster MG, Anderson IS, Henstridge RM Decontamination of *Bacillus anthracis* on Gruinard Island" *Nature* 1983;303:239-240.
28. Kennedy JF. *Why England Slept.* Westport, Conn: Greenwood Press Inc, 1981.
29. Bernstein BJ. The birth of the US biological-warfare program. *Sci Am.* 1987;256(6):116-121.
30. Dyson F. *Disturbing the Universe.* New York, NY. Harper & Row Publishers Inc; 1979.
31. Smith RJ New army biowarfare lab raises concerns. *Science.* 1984;226:1176-1178
32. Capps L, Vermund SH, Johnsen C Smallpox and biological warfare: the case for abandoning vaccination of military personnel. *Am J Public Health* 1986;76:1229-1231
33. Hu H, Cook-Degan R, Shukri A. The use of chemical weapons: conducting an investigation using survey epidemiology *JAMA.* 1989,262:640-643.
34. Spiers EM *Chemical Warfare.* London, England: Macmillan Publishers Ltd; 1986.
35. Marshall E. Sverdlovsk. anthrax capital? *Science.* 1988,240:383-385.
36. Palca J Anthrax outbreak in Soviet Union due to natural causes? *Nature* 1988;332·674
37. Dickson D. Soviets discuss Sverdlovsk. *Science.* 1986;234:143-145.
38. Meselson MS The Biological Weapons Convention and the Sverdlovsk anthrax outbreak of 1979 *FAS Public Interest Rep.* September 1988;41:1-6
39. Falk R. Dangers to avert. *Science.* 1989, 243:552-553
40. Akimov NI; Rimshaw SJ, trans. *Civil Defense.* Oak Ridge, Tenn US Dept of Energy, Office of Scientific and Technical Information; 1971. Publication ORNL-tr-2306.
41. Yegorov PT, Shlyakhov IA, Alabin NI *Civil Defense· A Soviet View.* Washington, DC: US Air Force, 1970.
42. Gouré L. *Soviet Civil Defense Public Instruction and Training Programs.* McLean, Va: Science Applications Inc, Center for Soviet Studies, 1984.
43. Atyunin NR. *How to Eliminate Chemical Contamination* [filmstrip] Moscow, Union of Soviet Socialist Republics: Diafilm Studio; 1968 (D-287-68, T11197). In· *Soviet Civil Defense* [videotape with English translation] Cave Junction: Oregon Institute of Science and Medicine, 1989.
44. Gouré L. *Shelters in Soviet War Survival Strategy.* Coral Gables, Fla. University of Miami. Advanced International Studies Institute; 1978.
45. Robinson AB Standardized steel shelters for a national shelter program. *J Civil Defense.* December 1988;21:18-22
46. Federal Office of Civil Defence Information Service. *Life in a Shelter.* Berne, Switzerland· Federal Office of Civil Defence; 1983.
47. Gardner J, Gerry E, Jastrow R, Nierenberg W, Seitz F. *Missile Defense in the 1990s.* Washington, DC: George C Marshall Institute; 1987.
48. Abrahamson JA. *End of Tour Report.* Washington, DC US Dept of Defense, Strategic Defense Initiative Organization; 1989.
49. Jastrow R. *How to Make Nuclear Weapons Obsolete* Boston, Mass: Little Brown & Co Inc· 1985