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**OVERVIEW OF CHEMICAL AND BIOLOGICAL WARFARE**

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A number of books have dealt with the history and more recent developments in the field of chemical and biological weapons (Haber, 1986; Vedder, 1925; SIPRI, 1971; SIPRI, 1973; Harris and Paxman, 1982; Seagrave, 1981; Marrs, Maynard, and Sidell, 1996; Sidell, Takafuji, and Franz, 1997).

Modern chemical warfare began with the extensive use of chemical agents during World War I, initially with German use of industrial chemicals, such as chlorine and phosgene, and later use of agents tailored for military use such as the mustards. Their effects were impressive but not decisive, although Russia suffered enormous casualties from chemicals. All combatants made some use of chemicals. There was considerable research on both agents and protective equipment.

World War II combatants possessed chemical and biological weapons, although the agents were little used, other than Japan's use of such weapons against China early in the war. The Germans did, however, use chemicals in their extermination centers. The reasons for nonuse were complex and went beyond simple mutual deterrence. The views of national political leaders, equipment and training of troops, assimilation of doctrine, perceived tactical or strategic advantage or vulnerability, operational readiness, existence of alternative means, and technical preparedness all were important factors. In several situations during the war, use of chemical or biologicals was very seriously considered, e.g., in the defense of the United Kingdom (UK) against invasion and in dealing with Japanese island defenses (Utgoff, 1998). Research and development activities were intense during the war, with Germany developing nerve agents and with biological warfare programs and weapon development in several other countries (Office of Scientific Research and Development [OSRD], 1946; SIPRI, 1971; SIPRI, 1973).

During the tense Cold War, there was extensive research and development, and both sides deployed weapon systems. Both sides also spent considerable effort on improving defensive systems. During this period, there were sporadic reports of chemical and biological employment in remote regional conflicts

(Crocker, 1984; Cordesman and Wagner, 1991; SIPRI, 1971). In the declining days of the Cold War, some regional powers, such as Iraq, Iran, and Libya, developed and employed chemical and perhaps biological weapons.

Chemical and biological weapons are capable of use across a wide spectrum of warfare, from acts of assassination and small-scale terrorism to various tactical and operational situations, both defensive and offensive, including strategic population attacks. The technical and economic barriers to development and weaponization have decreased.

Although a few chemical agents, such as phosgene, chlorine, and phosgene oxime, may degrade materials (corroding metals, degrading rubber), chemical and biological agents are primarily directed at humans and other living organisms and, unlike nuclear weapons, spare equipment and facilities.

The selection of an agent for use is more complex than a simple judgment of toxicity. Production, stability in storage, persistence, delivery, and dissemination are also important. It is not surprising that Iraq selected some agents that were known but not favored by other countries. For example, the Germans independently discovered lewisite during World War I but chose not to use it because they thought its prompt production of symptoms was a disadvantage. Other countries thought otherwise. It should be kept in mind that military agents often contain stabilizing chemicals that have their own toxicity, but most laboratory research on agent effects is done with chemicals purer than weapon-grade material and thus may not predict all effects of chemical weapons. The objectives of use can affect agent selection, from creating defensive barriers that deny entry to territory and facilities using persistent agents, such as mustards or VX, to supporting attacks with highly toxic but volatile nonpersistent agents, such as sarin.

Agents were once released from pressurized cylinders, but contemporary delivery systems make substantial use of modified conventional bomb and shell systems, although spray tanks and bomblets designed for agent delivery are also used.

Iraqi forces had a variety of delivery systems available: toxin loads for Scud missiles; aircraft using bombs or spray tanks, including unmanned aircraft; and artillery-delivered systems using shells and free rockets. Chemical mines were theorized at the beginning of the war (although no such mines were found after the war). Although Saddam Hussein spoke of binary weapons, no such binary delivery systems have been reported since the war.<sup>1</sup> In general, Iraq's delivery systems were not sophisticated, e.g., Iraq used simple bursters in shells to dis-

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<sup>1</sup>In a binary weapon, the component chemicals are kept separate, to be combined on launch.

seminate ricin rather than the more efficient bomblets, which the United States had developed during World War II. There would be indications of some technical prowess if the report from 1986 of micronized aerosol systems to deliver mustard were correct (Dunn, 1986; Marshall, 1997; UN, 1984; Zilinskas, 1997; Cordesman and Wagner, 1990).

Although there had been discussions of “dusty” (particulate) agents for some time, Iraq, in the war with Iran, made innovative and effective use of mustard agent adherent to fine silica particles to obtain more rapid and more damaging effects (OSAGWI, 1990; OSAGWI, undated b).

Specialized units appear to have been involved in chemical employment (Cordesman and Wagner, 1990), at least in large-scale operations, but little has been published about Iraqi chemical command and control and doctrine. Descriptions of the weapons U.S. forces destroyed at Khamisiyah indicate that there were no special markings obvious to U.S. forces, raising the possibility that inadvertent use might occur, since the chemical rounds resembled standard munitions.

As improved defensive systems arose, with wide availability of protective masks, chemical weapon designers moved in two directions. One was to develop means of mounting high-concentration attacks with very toxic agents that would be lethal with one or two breaths; even a small leak in a mask would produce dangerous incapacity. Such attacks using sarin might require several hundred pounds of agent on an area the size of a football field. Another means of surprise is the “off target attack,” in which a dangerous concentration of agent is established away from the target and is then allowed to drift over the target. Commanders prefer predictable results, and this technique is very sensitive to meteorological conditions (SIPRI, 1973; U.S. Army Command and General Staff College, 1963). Reference books on the use of chemical and biological weapons provide guidelines on downwind hazards for various weights of agent along a width of sector under different weather conditions, although the tables usually show a maximum distance hazard of 100 km for large amounts and inversion conditions. The second direction designers took was to attempt to deliver agents via the skin using either formulations of the agents combined with chemicals to increase skin penetration or designed to have skin-penetrating properties, such as mustards and VX. This in turn has led to widespread use of protective garments.

It is not widely understood that agents with delayed effects can be very effective. Delayed effects generally cover a period of hours to several days or longer. Delayed toxins are very attractive for assassins, terrorists, and special operations, providing very high toxicity for small weight and permitting escape before the attack is obvious. Botulinum toxin may have been used to kill an SS commander in Czechoslovakia in World War II (Harris and Paxman, 1982; Sidell,

Takafuji, and Franz, 1997). Mustard agents are a further example of efficacy arising from delayed effects. They are not readily detectable by smell<sup>2</sup> or other quick-acting physiological responses or warning properties, so large numbers of personnel may be injured before the danger is recognized. The low lethality of such agents is not necessarily a disadvantage, since care of the disabled is demanding. In World War I, 2 percent of fatalities were mustard casualties (Vedder, 1925).

The use or threat of use of chemical and biological weapons imposes considerable burdens on the defender. It is very difficult to rapidly detect all threats or to recognize all attacks in a complex military environment. Although modern protective equipment is highly effective, it poses very heavy burdens in many circumstances, e.g., heat stress; impaired vision, dexterity, communications, and control; and psychological stress (Taylor and Orlansky, 1993; Carter and Cammermeyer, 1989). The aggregate of these burdens is such that there is an incentive to employ chemicals enough to force an opponent into protective posture, to degrade tactical performance quite independent of any casualties actually produced (Franke, 1967).

Fear and confusion are prevalent in combat. Use or expected use of chemical weapons could further amplify that fear and confusion. During World War II, there were instances of U.S. units on Guadalcanal and in Normandy becoming disorganized at night when gas alarms sounded after troops had discarded their masks. More recently, it appears that fear of a chemical attack appears to have been a factor in flight from urban areas during the Iran-Iraq War, as both sides fired missiles at cities (Cordesman and Wagner, 1990). The high state of training and discipline in U.S. forces appears to have prevented panic during the tense periods of the Gulf War.

The following chapters provide a number of human toxicity estimates, many of which required some extrapolation from animal studies. The Subcommittee on Toxicity Values for Selected Nerve and Vesicant Agents (National Academy of Sciences [NAS], 1997) has pointed out that much of the older literature on these matters was developed to assess the effect of offensive use of such agents. In an offensive operation, the goal is to kill or incapacitate a minimum of 50 percent of the least-sensitive individuals in the target population, which actually results in greater damage when the more-sensitive population is considered. This bias in the older studies results in an understatement of the toxicity of agents and precautions needed to protect personnel.

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<sup>2</sup>Mustards do have a detectable odor at the level of biological injury, 0.006 mg/m<sup>3</sup> (OSRD, 1946).