Chemical and Biological Weapons: New Questions, New Answers

(See Munro et al., p. 933; Burrows and Renner, p. 975; and Reutter, p. 985)

The words "chemical and biological weapons" (CBW) send a shiver down most spines these days. With the end of the Cold War, the possibility of a massive nuclear confrontation appears remote, so today many popular doomsday scenarios center on the aggressive use of chemical or biological warfare by rogue nations or terrorist groups. As exaggerated as some of the accounts are, with CBW cast as the latest unseen, unstoppable enemy, the threat posed by these weapons is all too real, and growing.

Although most of the CBW agents involve often complex technical challenges to be met before they can be effectively weaponized (used as weapons) and delivered to a target, those challenges can be overcome with the right combination of expertise and resources. Even in crude form and delivered in a crude fashion, CBW agents can have a devastating impact. This sobering reality was realized on 20 March 1995, when members of the Aum Shinrikyo religious cult released the nerve gas sarin in the Tokyo subway. Twelve people were killed and more than 1,000 were hospitalized of the more than 5,000 who received medical attention. The material was impure and the delivery method was extremely crude, but with that attack against civilians during peacetime, and with the worldwide attention it received, CBW agents graduated from being a concern of the battlefield to a potential nightmare of our daily lives.

The likelihood of a CBW attack in some form on American citizens or military personnel is increasing; many experts characterize it as a matter of when, not if. In a 1997 press briefing (*1*) on the release of a report on weapons of mass destruction, Defense Secretary William Cohen said, "The threat is neither far-fetched nor far off … one that's only going to grow with time." Cohen noted that terrorist organizations now possess the capability of using such weapons. "The front lines are no longer overseas. It can just as well be in any American city," he said.

Fortunately, as the threat of a nuclear Armageddon has waned, more attention has been paid to how we can defend ourselves against CBW agents in both military and civilian settings. In 1998, the Department of Defense (DoD) ordered that all U.S. military personnel be vaccinated against anthrax, which is considered to be the biological agent most commonly weaponized and therefore the one most likely to be unleashed on U.S. forces. The DoD is also funding dozens of innovative research initiatives in CBW detection, decontamination, and medical treatment through its Defense Advanced Research Projects Agency (DARPA). Among these projects are a new protective helmet designed to shield against harmful pathogens, a "canary on a chip" bioweapon detector made of living nerve cells embedded in silicon, and artificial antibodies capable of being quickly customized to fight off a specific biological agent.

Soldier protected from chemical warfare.

DARPA funds the potentially revolutionary projects. However, they represent just the tip of the iceberg when it comes to scientific inquiry in the CBW field. Many other studies are in progress, which will add significantly to the body of knowledge about these substances. The papers by Reutter, Burrows and Renner, and Munro et al., each in their own way, contribute new levels of understanding of CBW agents and the threat they represent to people and the environment. Each paper adds important points to the storehouse of data regarding CBW agents and illuminates gaps in the data that should be filled by further research.

Perhaps the most troubling issues are raised by Sharon Reutter of the Toxicology Team at the U.S. Army Edgewood Chemical Biological Center at Aberdeen Proving Ground, Maryland, in her article "Hazards of Chemical Weapons Release during War: New Perspectives." Reutter's thesis is that today's potential uses of chemical weapons have changed dramatically since the compounds were first developed, and that scientific analysis of the materials and their toxicologic effects must change to accommodate those contemporary scenarios. According to Reutter, "the way we look at the toxicity of the chemical agents has changed. And people don't realize that when they see some of the reports that have come out lately. It's not that anything has changed about the agents, but we're asking different questions, and that makes the answers different."

When the original research and development work was conducted, says Reutter, "people were designing weapons of war, and they were trying to figure out how much killed how quickly—or how little it would take to kill how quickly, because you obviously want something the more potent the better, within limits." Most of the research was done on animals. A few studies, using low doses to produce relatively mild effects, were performed in humans—usually young, healthy males, who were then the likely targets of a chemical attack. Although those data are invaluable, they are inadequate to answer the new questions arising from the new perspectives Reutter describes. Today's population for possible exposure to chemical weapons is much broader. Even when only considering the so-called chemical battlefield comprising only military personnel, new questions abound because of the presence of many women in the armed forces. The limited data available appear to point to differences in the sensitivity of women to chemical agents as compared to men. New targets have brought about a need for new data.

With chemical weapons currently in the hands of terrorists, those new targets include everyone—the civilian population, with people of all ages and states of health. Reutter states flatly that "it should be assumed that a civilian population would be more sensitive than a military population"—perhaps as much as a 10-fold difference.

Assessing the impact of CBW agents on today's targets is further complicated by the need for much more information about the effects of sublethal doses of chemical agents. What long-term effects will these poisons have on people who are exposed to low doses over an extended period of time, which is a likely exposure scenario today? The paucity of data addressing that question becomes clear in Reutter's paper, as she compiles much of the existing toxicologic information about each specific agent. Also lacking is information about the spectrum of dosages, ranging from very low doses that produce very mild effects to doses that are just sublethal. As Reutter states, "there are still many unknowns in the linearity of the dose–response curves of the agents over time." Answers to those and other similar questions will be crucial when today's hypothetical targets become tomorrow's

actual victims. It is to be hoped that the scientific community will respond quickly to this particular wake-up call and endeavor to fill in the data gap identified by these new perspectives on killer compounds that have been with us for a fairly long time.

Biological weapons are clearly a danger, but thanks to "Biological Warfare Agents as Threats to Potable Water," there is at least one apocalyptic vision that can be taken off the list of CBW anxieties. The ultimate message of W. Dickinson Burrows and Sara E. Renner of the U.S. Army Center for Health Promotion and Preventive Medicine (Aberdeen Proving Ground, MD) is that a terrorist attempt to contaminate a large-scale water supply in an American city with a biological weapon is not only highly unlikely to take place, but is highly unlikely to succeed if it does. In both cases, of course, highly unlikely is not the same as impossible. "It's not, at least in a municipal consideration, a cause for great alarm, but certainly a cause for reasonable vigilance," says Burrows, an environmental engineer specializing in water. He notes that it is important for a municipal waterworks to have a sound security program, with fencing of the facility and some provision for guarding it, but that such security measures are realistically intended to ward off vandals as much as terrorists.

The practical challenges to such an attack would be formidable. Some of the 18 replicating agents and 9 biotoxins known or suspected of having been weaponized are not waterborne threats. Others would be easily inactivated or removed by the normal chlorination and filtration processes in municipal water supplies. Finally, Burrows and Renner state,

> With few exceptions the dose of any BW [biological warfare] agent required to cause adverse health effects is of such magnitude as to make essential the targeting of water supplies closest to the consumer…. Targeting of large bodies of water such as water supply reservoirs would be impractical….

Of much greater concern is the potential of many of these agents to contaminate battlefield water supplies, whether they are intentionally targeted or are tainted as a collateral result of an aerosol BW attack. Even so, a properly functioning field water treatment system appears to provide a stout defense against most of the BW agents. In fact, the authors speculate that

> the greatest risk of injury could be to those who service the water treatment equipment and are exposed to the agents at the highest concentration.

Nonetheless, the threat exists and must be taken seriously. Burrows and Renner call for further development of BW detection equipment, more testing of BW agents to determine their individual tolerances to chlorine and other disinfection methods, and studies of the efficacy of the various individual point-of-use water purifiers in removing or inactivating BW agents. Each of these research initiatives would be important additions to the body of literature addressing this issue.

"The Sources, Fate, and Toxicity of Chemical Warfare Agent Degradation Products" by Munro et al. also contains, in the midst of some extraordinarily detailed and complicated chemistry, a gem of good news for the general public. Now that the United States (along with most of the other countries in the world) has formally renounced the use of chemical weapons, the sites where the agents were produced, tested, and stored must be cleaned up and decontaminated; existing stockpiles, some decades old, must be destroyed. Some of the stockpiles have been buried, some have been stored in less than ideal conditions, and some have simply deteriorated with age. Leakage and contamination of soil have occurred in some instances. It is valid for the public to ask whether any of these sites are environmental disasters in the making. Could a deadly nerve agent leach into groundwater and contaminate drinking water?

Munro et al. provide a measure of reassurance that these stockpile sites do not constitute a major cause for environmental concern. The authors provide an exhaustive review of the literature regarding the chemical makeup of the breakdown products of each of the known chemical weapons, paying particular attention to the toxicity and persistence in the environment of those degradation products. Fortunately, for the most part, the chemical agents break down fairly rapidly when exposed to the elements. According to coauthor Sylvia S. Talmage of the Life Sciences Division at the Oak Ridge National Laboratory, Oak Ridge, Tennessee, "It was a nice, pleasant surprise to see that these things are mostly not persistent, but they will break down naturally, and most of the breakdown products are less toxic, and some practically innocuous." Also, says Talmage, "There are many people, many researchers, working on ways to take what is there at these sites, whether the drums are intact or not, and denature them, decontaminate, break down the product, speeding up the process that can be used to break down the chemicals…. These problems are being solved."

Those researchers, and the personnel responsible for the on-site work of cleanup and decontamination, will no doubt find the paper by Munro et al. to be an invaluable resource in the course of their pursuits. It is a thorough compendium of the existing data on these sometimes obscure chemicals, and the authors have performed an important service by gathering so much of this information in one place.

Despite the best efforts of civilized people around the world, chemical and biological weapons and the many-faceted threat they represent are here to stay. As with nuclear weapons, the genie can't be stuffed back in the bottle. However, the work of these researchers, and countless others like them, does lend some comfort. The scientific community is responding to the CBW challenge, providing innovative and vital new answers to the new questions being posed.

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References and Notes

1. DoD. DoD News Briefing. Proliferation: Threat and Response Briefing. Washington, DC:Department of Defense, 1997. Available: http://www.defenselink.mil/news/Nov1997/t112597_t1125ptr.html [cited 19 October 1999].