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Historically, nature has been the source of widespread death, famine, and economic destruction. The question before us now is whether mankind will manipulate nature so as to cause such hardship purposefully. The purpose of this essay is to describe biological and toxin agents, the means of their weaponization, and who might undertake to make such weapons. Additionally, U.S. vulnerabilities to biological and toxin weapons attacks will be discussed, together with steps we might undertake to better manage the consequences of such an attack.

Introduction

We all know that hundreds of thousands of people can be killed by an epidemic of a disease. Even a disease that is now considered commonplace, influenza, can cause tremendous mortality. For example, more than 500,000 deaths resulted from the influenza pandemic of 1918-19.[1] The plague, malaria, West Nile virus, AIDS and a host of other diseases afflict man, occasionally erupting as pandemics.

Similarly, we are well aware that economies can be devastated when diseases harm or kill food animals. Foot-and-mouth disease,[2] a highly infectious virus spread via inhalation or ingestion, has occasionally broken out in herds of beef and dairy cattle worldwide. The only option to contain the disease has been the costly destruction of animals. A 1997 outbreak of the disease in Taiwan resulted in destruction of over 500,000 tons of pork and an overnight drop in the nation's GDP of 2%.[3] The U.S. Department of Agriculture (USDA) has estimated that a limited outbreak foot-and-mouth disease—one that is limited to 10 or fewer farms and which is quickly diagnosed and eliminated—would cost the United States a minimum of $2 billion.[4]

Similarly, major plant crops have been attacked by fungi and other disease-causing agents, resulting in economic losses and, at times, famine. A well-known case was the Irish potato famine of 1845-46, caused by a fungus. More than one million people died in the resulting famine, and 2 million or more emigrated. Such events have occurred in the past due to the vagaries of nature.

However, there is also a history of diseases and toxins being spread purposefully to debilitate or destroy opponents. Scythian archers used arrows dipped in blood and manure or decomposing bodies in 400 BC. In Medieval times, infected cadavers were catapulted over castle walls by invaders to cause disease and debilitation of those under siege. In 1763, blankets that had been used by smallpox victims were distributed to native American Indians with the intention of spreading the disease to them. In 1952, African bush milk (a plant toxin) was used by the Mau Mau to infect steers at a Kenyan mission station.[5]

An abiding fear of U.S. national security planners is that an epidemic will be caused purposefully by man, leading to massive destruction. Pathogens or their toxins could be used to destroy crops, animals, humans, and materials[6]. This fear is not without foundation; the number of times that the Federal Bureau of Investigation has responded to incidents involving a threat to use biological weapons in the United States has increased dramatically in recent years.[7] And, notwithstanding claims by some observers, biological and toxin weapons are indeed relatively easy and inexpensive to make.

The Nature of Biological and Toxin Weapons

Biological agents are disease-causing organisms and materials[8]—whether viral, bacteriological, rickettsiae, fungal, or protein—that can cause damage to or death of humans, other animals, or plants. Toxins are the harmful chemicals that can be produced by bacterial, marine organisms, fungi, plants, and animals. Biological and toxin weapons (BTW) are devices, such as aerosol sprayers or munitions, designed to deliver biological agents to a target population.

Bacteria are single-cell organisms.[9] A widely discussed bacterial agent is *Bacillus anthracis*, a hardy bacterium that causes the highly lethal disease pulmonary anthrax. One gram of anthrax theoretically contains 10 million lethal doses. Inhalation of 1000 spores of anthrax or less can produce fatal pulmonary anthrax in some members of an exposed population; 8000 spores, weighing 0.08 microgram, is fatal to a large proportion of those exposed.[10] Anthrax is easily and inexpensively produced. It also has a long shelf-life; spores can survive more than 40 years.

Rickettsiae are bacteria that can only reproduce inside of animal cells. A well-known example is *Coxiella burnetii*, which causes Q fever.[11] It is extremely infectious; a single organism *of Coxiella burnetii* can cause infection in a human. Because it can create a spore-like form, it is highly survivable and is relatively easy to manufacture in quantity and to disseminate.

Viruses are intracellular parasites consisting of a strand of genetic material (DNA or RNA) surrounded by a protective coat that facilitates transmission from one cell to another. Variola virus, which causes smallpox, was explored by the Japanese military as a biological weapon in China during the years just prior to WW II. The virus would make a "good" weapon because it is not only highly lethal, but also there is an effective vaccine that could be used to protect the population and troops of the user. (Smallpox vaccine is no longer used to inoculate the general population worldwide because the disease is presently eradicated.)

Fungal agents ordinarily do not cause disease in healthy humans, although they can be devastating to those with deficient immune systems. Rather, fungi that have been developed as weapons have predominantly been those that cause diseases of plants. Rice blast fungus, for example, is an agent that can cause massive economic damage and, in some situations, starvation. Little of the fungi is required to make a potent weapon; experiments have shown that 3 g of rice blast fungi per hectare could infect between 50% and 90% of the crops exposed.[12]

Some proteins can be used as weapons. Most bacterial toxins are large proteins that affect either the nervous system (neurotoxins) or damage membranes. An example of a neurotoxin is the toxin secreted by *Clostridium botulinum*, the most poisonous substance known. The fatal dose of botulinum toxin A by injection or inhalation is about 1 nanogram (billionth of a gram) per kilogram. It is fast-acting, usually causing death in 1-3 days in the majority of victims. Staphylococcal enterotoxins (an incapacitant) and botulinum toxin are 1000- to 10,000-fold more toxic than classical nerve agents.

There are weapons-usable proteins that are not derived from bacteria. Ricin is a well-known example of a protein derived from a plant. It is produced by the castor bean and is readily available throughout the world. It is simple to separate ricin; individuals lacking any formal biology training have successfully produced large quantities of the poison. Venoms of various types are derived from animals. And, because the DNA sequences or genetic blueprints of many venom toxins have been determined, they can be produced in large quantities by molecular biological techniques.

Another protein which could conceivably become a weapons threat in the future is prions.[13] Prions are the protein that causes some neurodegenerative diseases, most notably bovine spongiform encephalopathy (BSE aka mad cow disease) and variant Creutzfelt-Jakob disease. Although a prion

disease might be too slow-acting to be attractive to a BTW user, it is conceivable that the disease could be used as a weapon to cause terror and severe economic repercussions. A BSE outbreak in the United Kingdom during the 1990s cost the British Government between U.S. $9 and $14 billion in compensation paid to farmers. The massive expenditure forced a sale of state-owned bonds, led to increased inflation, and put off implementation of interest rate and tax policies.[14] Similar drastic effects could result from, for example, a terrorist deliberately introducing tissues infected with prions into the food of cattle[15] or humans.

In addition to protein toxins, there are low-molecular-weight toxins, which may be either organic molecules or peptides. Examples of low-molecular-weight toxins are saxitoxin, a neurotoxin found in some shellfish, and trichothecene mycotoxins, which are produced by fungi. Some low-molecular-weight toxins can be produced by chemical synthesis.

A theoretical possibility is that bioregulators—organic chemicals that regulate cell processes—and physiologically active compounds such as catalysts and enzymes could be used as weapons. They could be used to cause effects such as rapid unconsciousness, heart failure, or paralysis.[16]

Not all disease-causing agents are suitable for weaponization. In addition to the characteristics of the disease itself, there may be limiting features that make the agent difficult to make and deliver. A perpetrator probably would seek an agent that has high virulence, is easy to disseminate, and can remain effective from the time of production to the time of infection of victims. A consideration may be the time of incubation between infection and onset of symptoms. This would be particularly important if the target were to be military personnel in time of battle. Another consideration may be whether there are readily available vaccines or medical treatments for the disease that could mitigate the effects of the weapon.

Historically, toxins have been thought to be more likely chosen as workable terrorist weapons[17] than as weapons of mass destruction. This is because some toxins have been too difficult to produce in quantities that would make them usable in battlefield scenarios and some have had stability problems that make them unattractive weapons. These variables are less likely to be limitations today because of the advent of genetic engineering. In fact, toxins may be an increasingly used weapon in the future because they can be very stealthy and highly effective.

Production of Biological and Toxin Agents

BTW agents are derived from nature. Any nation, group, or individual that wants to acquire such weapons can readily find the pathogen or source for most of the toxins and diseases that could be used as weapons against man and agricultural crops and animals. While much was made in the news media recently about the availability of pathogens through supply houses for research, most known BTW programs have not needed to rely on commercial availability. Once the pathogen or source is acquired, the agent can be produced in the desired quantity, using standard biological techniques and equipment, and then weaponized.

Production of biological agents utilizes materials and equipment that are dual-use. The same hardware, growth media, etc. that are used in commercial fermentation and biotechnology industries can also be used to make agents for weapons. This materiel is available worldwide through catalogs and supply outlets. Furthermore, makeshift equipment and materials such as home brewing fermenters and pressure cookers could be used if there were difficulty in acquiring biotechnology supplies.

The knowledge of how to produce agents is the same as the knowledge required for legitimate biological research and production. There is no way to limit either the tools or the capabilities to produce biological and toxin weapons because they are the same as those needed for legitimate basic research and

commercial interests. Work on weaponizable agents can involve the same type of activities as work on weapons. A well-known example is the fact that botulinum toxin A is now a therapy for at least twenty-five nervous system disorders.

Manufacturing agents in militarily significant quantities can be accomplished in only a few days using a small, easily concealed facility. If the BTW project is very limited in scope, production could be accomplished in a bathroom- or garage-sized homemade laboratory. This is what the members of the Japanese cult Aum Shinrikyo did: they produced anthrax and botulinum toxin in a laboratory they constructed in room in a nondescript building. In 2001, a U.S. Government contractor proved that a facility for manufacturing biological weapons could be built, using off-the-shelf technology, for less than $1 million.[18] A larger-scale plant capable of producing more agents in greater quantities could be built for approximately $10 million.[19] Alternatively, a facility that normally engages in legitimate activity—such as vaccine production, medical laboratory analyses, or single-cell protein production—could be briefly dedicated to BTW agents production.

The level of safety required to protect workers varies with the danger presented by the pathogen or source. High containment facilities that utilize measures such as filters, positive airflow, or protective suits are costly and difficult to maintain, but they are not necessary. If safety is not a priority, most BTW agents can be produced in very low-level containment facilities. Iraq, for example, manufactured several BW agents in facilities that were not of the safety standard that would be required in most Western countries.

Rapid advances in biotechnology in the past three decades have revolutionized the processes available for production of pathogens and toxins. Whereas in the past toxins had to be produced by labor-intensive means, new techniques enable rapid production of large quantities via manipulation of toxin genes in bacterial, yeast, baculovirus, and mammalian production systems. Genetic engineering has made it possible to manipulate the genetic characteristics encoded in the chemical structure of the DNA molecule. This creates the potential for creating “designer” biological agents that could be easier and faster to produce, more lethal, and which could present difficult-to-diagnose symptoms not treatable by known means. It may also facilitate making “traditional” BTW agents more stable and less susceptible to current vaccines and medical treatments.

Unless the BTW agent is itself stable, like anthrax, there is need to take measures to enhance survivability so that it can be stored and will be viable long enough to infect when used. Freeze-drying, cold storage, chemical additives, and microencapsulation are techniques that can help stabilize some agents. Alternatively, a perpetrator may choose to maintain a facility and produce the requisite agent just prior to using it.

Weaponization and Delivery

BTW agents can be delivered in a variety of ways. Saboteurs could put agent into the water system or food supply of a target, such as a city or military encampment. Vectors, such as disease-carrying insects or animals, could be released into the target’s population—a method that is both relatively slower and less sure in its effects.[20] A few individuals could be inoculated with highly infectious disease that would be likely to spread (e.g., some cattle could be infected with foot-and-mouth disease). Or, mechanical weapons could be devised to remotely and quickly deliver an aerosol cloud to a specific location. The means selected will depend on how much time the user wishes the process to take. A user who does not want to be identified and who wishes the attack to appear to be natural may choose to attack with a vector-borne disease. A user that needs quick effects against the troops of a military foe will probably depend on mechanical delivery of the agent.

Mechanical delivery of BTW against a target population, whether animal or plant, does not involve complex technology, but it does require care and skill to assure that the agent used remains potent and is in a form that can affect the victims. For example, bacterial and viral diseases, as well as freeze-dried toxins, that are spread by inhalation can require a stable cloud of suspended particles. Because large particles would settle quickly, it is critical that the agent particles be between 1 and 5 microns in diameter. This will not only allow the agent to remain suspended, but also will be of a size more likely to be retained in the human body. Inventing this technology was extremely difficult, but recreating it can be relatively easy, given the availability of modern equipment and the spread of relevant knowledge.

Although aerosol technologies are not highly demanding, it should not be assumed that any agricultural sprayer will accomplish the job. Pesticide and fertilizer sprayers do not maximally produce particles in the 1 to 5 micron range. While a standard off-the-shelf sprayer can spread BTW agents in a manner that could cause harm, it will not do so efficiently.

Delivery mechanisms that can produce an effective cloud of biological or toxin agent include aerosol sprayers, bombs, munitions, and rockets. It is important that the delivery mechanism does not create so much stress that it destroys the BTW agent. For this reason, delivery systems that rely on explosives for dissemination present greater technical challenges. Although these difficulties have been overcome (e.g., the United States deployed anticrop cluster bombs in 1951), non-explosive disseminators are simpler.

In addition to developing a mechanical delivery device that will deliver BTW agent in an effective aerosol, weather and conditions must be gauged properly. A light breeze to assist in spreading the cloud without dispersing it is desirable. Temperature, presence of sunlight, and humidity may also affect dispersal and potency of the agent.

Who Would Use BTW?

Because BTW agents are relatively simple and inexpensive to produce without detection, potential users include nations, groups, and individuals. A user might be a mentally unstable person who, without ever being identified, introduces a biological or toxin agent into the food, air, or water supply of a town. Or, it might be a nation or subnational terrorist group that openly attacks a U.S. installation with BTW, including missiles and other delivery systems. The possible scenarios are endless. To understand the options and the relative level of threat they represent, it would be useful to outline known programs and a few examples of recent threat incidents involving BTW. First, examples of national BTW programs will be discussed, then two subnational programs will be described.

In the last century, there were eight nations whose BTW programs were fairly well documented: Germany, Britain, Japan, United States, Canada, USSR/Russia, South Africa, and Iraq.[21] Many other nations are very likely to have programs, although documentation on them is less thorough than for the eight. They include: Belarus, China, Cuba, Egypt, India, Iran, Israel, Libya, North Korea, Pakistan, South Korea, Syria, Taiwan, and Ukraine.[22] And, as previously noted, there are no substantial financial or technical obstacles to any nation that would wish to have a BTW program.

Although some nations, including Britain, Canada, and the United States, destroyed their BTW programs in compliance with the 1972 Biological and Toxin Weapons Convention, others signed the treaty but remained clandestinely in noncompliance. Russia and Iraq are well-documented examples.

The Soviet Union began developing anti-personnel BTW in the late 1920s and anti-agricultural agents in the late 1940s, early 1950s.[23] The Soviet bioweapons research agency, Biopreparat, was established in 1973 and quickly grew to more than 32,000 scientists and staff, some 10,000 of which were devoted to

anti-agriculture projects.[24] It became the largest, most advanced BTW effort in the world, at one point consisting of some 40 institutes and facilities involving more than 60,000 personnel.[25]

"Traditional" agents—those developed by multiple countries during the timeframe 1940-1970—as well as engineered agents were manufactured and weaponized by the Soviet Union and, later, Russia. Biopreparat genetically altered known pathogens to make them resistant to Western drugs and sought to make new strains of diseases more powerful than those extant. In 1983, for example, the research institute at Obolensk developed Biopreparat's first superplague, a new strain of tularemia.[26] In 1995, Russian scientists disclosed at a conference in the United Kingdom that they had implanted genes from *Bacillus cereus*, an organism that causes food poisoning, into anthrax.[27] Also, the USSR is thought to have developed smallpox, the highly contagious and deadly disease thought to be eradicated from the world in the late 1970s, as a weapon.[28]

The Soviet program continued despite assurances from the nation's top leaders that it had ended. In 1979, there was an accidental release of anthrax from a Soviet BTW facility, killing at least 66 people. The Soviets claimed that it was a natural outbreak. In 1989, some defectors from the Biopreparat program gave details about the Soviet BTW capabilities that heightened interest and concern by Western governments. Then, in 1992, Russian President Boris Yeltsin confessed to the program and promised to end it. He also pledged to fire General Anatoliy Kalinin, who had led Biopreparat since 1973. Yeltsin made good on neither commitment.

Ironically, Biopreparat appears to have been partially funded in the 1990's by U.S. grants intended to wean Russian scientists away from weapons work. The U.S. National Aeronautics and Space Administration and the U.S. Agency for International Development both had multi-million-dollar assistance programs whose funds were diverted by the Russians to Biopreparat, which remained highly secret under General Kalinin's leadership.[29]

There is presently no way to know for certain whether Russia's BTW stockpiles remain or whether the research and development of BTW agents continues. It is certain, however, that Russia's capacity to manufacture and weaponize agent remains intact. Also, elements of the Biopreparat program remain secret and documentation on the past program has not been made public.

Iraq's BTW program was discovered during UN weapons inspections following the 1992 Gulf War. Information on the program came from defectors as well as from documentation found as a result of defectors' guidance. Although a great deal has been learned about the Iraqi program, the extent of BTW research, development, and weaponization still has not been uncovered. This is due to Iraqi obfuscation, including withholding of documents, hiding evidence, and moving facilities and functions to secret locations.

Although the quantities of agents produced remain in question, it is undisputed that Iraq manufactured multiple BW agents, including: *Bacillus anthracis* (anthrax), aflatoxin, *Clostridium botulinum* (spores and toxin), wheat smut, *Clostridium perfringens*, and the plant-derived toxin, ricin. Iraq also *produced Bacillus subtilis* and *Bacillus thuringiensis* (*Bacillus anthracis* simulants). Its weapon containing BTW agents included:

- **An aerosol generator**. The generator was based on a modified helicopter-borne commercial chemical pesticide disseminator. This system was successfully tested in August, 1988.

- **Al-Hussain missiles**. Iraq claimed to have destroyed some Al-Hussains at a site inspected by the UN Special Commission on Iraq (UNSCOM). Inspectors were able to gather some physical evidence that the warheads indeed carried BW agent.[30]

- **R-400 and R-400A bombs**. UNSCOM has stated that it is not possible to determine how many bombs were filled with which particular agents.

- **L29 trainer aircraft**. These were converted into unmanned aerial vehicles for BW delivery and fitted with two underwing tanks capable of carrying 300 liters of BW or CW agent.[31]

Iraq may also have researched and developed BTW agents beyond those declared. It is known that Iraq was researching genetic engineering, Tricothecene mycotoxins, and viruses. It may also have been working on two additional bacteria, *Brucella mellitensis*, which causes Brucellosis, and the bacterium that causes the plague. The three viral agents it conducted research on were infectious hemorrhagic conjunctivitis virus (Enterovirus 70), rotavirus, and camel pox. No plausible explanation was given by Iraq for these activities and it is probable that Iraq still has undeclared biological agents. Furthermore, it is reasonable to expect that Iraq resumed its BTW program after inspections were ended in 1998.

Iraq may have produced smallpox as a weapon. Iraq manufactured smallpox vaccine as late as 1989, a decade after the disease had been eradicated, and a freeze-drier labeled "smallpox" was found at an Iraqi facility involved in BW activities.[32]

In addition to national BTW programs, there have been numerous smaller-scale BTW efforts by individuals and subnational groups.[33] One example is the use of biological agent by a religious cult, the Rajneeshees.

The Rajneeshees, led by Bhagwan Shree Rajneesh, moved to the United States from India in 1981 and established a commune in rural Oregon. After coming into conflict with the local inhabitants, in 1984 the Rajneeshees devised a plot to seize political control of the county where they resided. They intended to expand voter rolls of those who would support their cause by importing homeless people. To decrease the numbers of those voters who would oppose them, they planned to spread diseases that would make the local inhabitants too sick to vote. In August and September, the Rajneeshees spread *Salmonella typhimurium*, which causes food poisoning, on the salad bars of the small town of The Dalles. (The Rajneeshees had considered using *Salmonella typhi*, the agent that causes typhoid fever, a disease for which the fatality rate can reach 10 per cent.) The Rajneeshees also attempted to infect the town's water supply. While the plot failed, the Centers for Disease Control and Prevention determined that 751 people became ill. More than 40 had to be hospitalized.

Another publicized example of BTW use by a subnational group was the production and use of biological weapons by Aum Shinrikyo, the Japanese terrorist cult. On at least four occasions, Aum Shinrikyo reportedly attempted to employ BTW agents.[34] In April 1990, Aum Shinrikyo outfitted an automobile to disseminate botulinum toxin through the engine's exhaust. The car was then driven around the building where Japan's parliament meets. In early June 1993, the cult attempted to disrupt the planned wedding of Prince Naruhito, Japan's Crown Prince, by spreading botulinum toxin in downtown Tokyo using the same automobile. In late June 1993, the cult attempted to spread anthrax in Tokyo using a sprayer system on the roof of an office building in east Tokyo. On March 15, 1995, Aum Shinrikyo planted three briefcases designed to release botulinum toxin in a Tokyo subway.

The reasons why the attacks were not successful are not publicly known. Japanese authorities have not released much information on the subject. One possibility is that the cult used a strain of *Clostridium botulinum* that is insufficiently harmful as a weapon.[35] Also, one at least one of the 3 occasions when botulinum toxin was the agent used, the individual responsible for filling the spreader reportedly had qualms about the planned attack and substituted a non-toxic substance.

The conclusion drawn by some observers that BTW are very difficult to make successfully, based on the failures of Aum Shinrikyo, are not valid. There are credible alternative explanations for the failures as well as substantial evidence that such weapons are indeed easy to make. The question remains, however: if these weapons are so easy and inexpensive to make, why have they not been used successfully before?

BTW agents have been used before, as noted at the outset of this essay. Yet, in recent history, they have not been used on the battlefield when they could have been (e.g., Iraq) and, as of this writing, have not been employed by terrorists. The fact that BTW have not been used by nations can be explained, at least in part, by the effectiveness of deterrence (more below). Non-use by terrorists is not well understood, but historically terrorists have been unwilling to cause large-scale loss of innocent life. Presumably this was due to their unwillingness to engender public opinion backlash. In the future, however, there is greater likelihood that BTW will be used, as will be discussed below. If these weapons are used, the United States is highly vulnerable to such attacks.

Why the U.S. is Vulnerable

Vulnerability is comprised of two essential features: the willingness and ability to pose a threat, and the inabilities or unwillingness of the potential victim to defend itself. When writing on this section began in early September 2001, it seemed that it would be difficult to make a convincing case that some one or some group would be willing to use BTW, even though it is a potential threat that has been much on the minds of defense planners. After all, BTW have been around for a very long time and no one in recent history, as far as is publicly known, has used it on a large scale. Additionally, it seemed that it would be difficult to explain convincingly that someone is likely to use BTW, not just against U.S. troops on a battlefield, but against U.S. citizens in a terror attack. In the literature on terrorism, many experts who address the notion of a weapons-of-mass-destruction attack on civilians dismiss it, arguing that terrorists do not want many people dead, they just want many people paying attention to their cause. Thus, because that there had been no terrorist attacks causing massive fatalities, and because there had been no willingness to use BTW, it seemed it would be hard to make the case that we should be fearful of terrorist use of BTW on a large scale.

The horrific events of September 11 changed reality as we know it. With the thousands killed in the terror attacks on the World Trade Center and the Pentagon that day, it is now clear that subnational groups, perhaps supported by nations, are willing to cause massive, indiscriminant death. It is also clear that the terrorists are enormously sophisticated in their techniques and use of technology. They are well-coordinated internationally, with ties to Syria, Iraq, and other states that have BTW.

The terrorists that struck on September 11 spent years in planning and preparation, including living in the United States and attending U.S. schools to learn to fly jet aircraft. They were intelligent and educated. Some had families. They were neither the total misfits nor religious fanatics we may have tended to think of when we paint a mental picture of Islamic zealots; some of them drank alcohol and enjoyed Western culture. And, they were willing to die for the cause of killing thousands of innocent civilians. They did not act alone; they acted in coordinated groups. Very probably, they were state-sponsored.

In the future, it is very possible, perhaps even probable, that terrorists will attack U.S. civilians and/or agriculture with BTW. For example, Iraq or Libya—both of which have BTW capabilities—may be sponsoring the terrorists. They are motivated not only by “anti-Zionist” ideology, but also by desire for revenge for attacks against them by the United States. Thus, they might lend their BTW capabilities to terrorists acting either independently, or on behalf of these states. It is known that the terrorists who acted on September 11 were interested in acquiring crop dusters, so it is indeed possible that they intended to spread BTW agents using these planes.

Given that there are actors with the capability and willingness to use BTW against the United States, we must look at the other side of the equation, i.e., how capable is the United States in protecting against and deterring such attacks? As discussed, most BTW agents must be inhaled or ingested to cause harm to humans or animals. Some biological agents may infect via vectors such as insects. Overall, U.S. capabilities to protect against purposeful spreading of diseases, regardless of the type and means of delivery, is very limited. Our food, water, and our very lives are at risk.

U.S. food supplies are at risk, primarily at the production stage. The spread of diseases to agricultural plants by spraying them with pathogens is not only very easy, but is an inexpensive means by which an adversary can wreak havoc on the U.S. economy. And, there is simply no way for the United States to protect against purposeful biological attacks against crops.

One of the reasons that U.S. agriculture is so susceptible to such an attack is the use of single crop types on large farms. "Modern crop production practices involving large-scale mono-cultures of genetically uniform plant types are rendered particularly susceptible to large-scale outbreaks of plant disease involving fungal plant pathogens."[36]

To understand the risk to agriculture of a biological attack, one need only look at the impact of a recent natural outbreak of Karnal bunt on wheat in the United States. In 1996, Karnal bunt—a smut disease caused by *Tellita indica,* which, incidentally, was researched and may have been weaponized by Iraq—was discovered on wheat kernels from Arizona. Extremely quick action was taken to quarantine and clean up the affected crops, a process that cost approximately $45 million. As a result, international trading partners agreed not to halt our $6 billion exports (annual), although they had the right to do so. Trade was diminished only by $250 in total losses.[37] There are a host of diseases that could devastate U.S. "breadbasket" crops so rapidly that their control would be difficult, if not impossible, to effect before catastrophic damage.[38]

Animals—chickens, cattle, swine, fish, etc.—are also potential agricultural targets. Cattle, for example, are raised in large numbers in a very few locations in the United States. "In California alone, which represents one of the country's most important cattle and dairy producing states, there are no less than 31 feedlots that have a capacity of at least 15,000 head, most of which are concentrated in just two regions—the Imperial and San Joaquin Valleys."[39] Said a bit differently, 78% of U.S. cattle are produced on 2% of feedlots and 85% of these feedlots can be found in seven states.[40]

This massing of cattle in few locations makes it extremely easy to spread disease quickly and therefore to have enormous economic impact. Also, it would be difficult to limit the spread of the disease. As a USDA official has estimated, an infection like foot-and-mouth disease could spread to as many as 25 states in as little as five days, simply through the regulated movement of animals between farm and market.[41]

There are also many BTW agents that can catastrophically contaminate water supplies, although contamination by poisons such as cyanide may be a more likely scenario. While standard water treatment processes can eliminate the effects of many agents, others would require expensive water treatment that is not normally used by U.S. water utilities. Physical protection against sabotage of water supplies would be an enormous undertaking, requiring many reservoirs to be covered or protected in other ways. Major pipelines to the consumer would also need physical protection. Water utilities have not extensively undertaken such measures not only because of their expense, but also because attacks against water are generally thought to be less attractive to adversaries than attacks directly against humans or agriculture.

The notions of BTW attacks against agriculture and water are fearsome, but they do not evoke the same level of fear as the scenario wherein the U.S. civilian population is attacked with a silent, almost invisible cloud of BTW agent. Most BTW agents, however, could be effectively defended against by donning a

protective mask. Of course, the potential victim must know in advance that the mask is to be put on, which requires foreknowledge such as accurate, timely intelligence or detection.

Although the United States has developed some capability to rapidly identify that a cloud containing organic material is present, it is not yet possible to detect all types of agents. Agents that are not anticipated or that are genetically altered will not be in the "library" of the detector. And, while detectors may be workable on a battlefield where BTW use may be anticipated, it is not practical to have such detectors in the millions of locations where agent may be used against civilians.

If we assume that there will not be detectors everywhere and that everyone will not carry a mask at all times, what protection might there be? If the perpetrator were to use an agent against which there had been widespread vaccination, obviously the effects of the attack would be limited. Because most of the U.S. defensive measures and programs are public, attackers are likely to know which diseases have effective vaccines and to avoid using these.

If the attacker were to use an agent against which there were an antidote or a treatment, the effects of the attack possibly could be mitigated. Effective treatment would depend on rapid, accurate diagnosis. It would also depend, of course, on the rapidity with which authorities could respond and the amount of medication or treatment available. Unfortunately, in the case of some diseases and toxins, the victim must be treated immediately—prior to onset of symptoms.

In summary, we do not have measures that can effectively prevent or neutralize the effects of all BTW agents. We do not have sensors or detectors that can tell us with surety when such agents are used. Although masks can be effective against BTW agents, providing them to the entire population is presently viewed as infeasible and, even if we were all to have them, we might not know when to don them. Vaccinations and prophylactics against agents likely to be used do not yet exist. Medical treatments and countermeasures may exist for some agents, but their effectiveness would depend on many variables, including knowledge that the agent was used and availability of supplies and medical personnel.

What Can Be Done?

Given that there are individuals, groups, and states with the willingness and ability to pose a threat to the United States, possibly with BTW, what can we do, and what are we willing to do, to deter the threats? And, if the attack occurs despite our efforts to deter, what can we do to manage the consequences of BTW use? Prior to discussing these vital questions, however, it is important to dismiss a notion put forward by some analysts and diplomats that arms control might contribute significantly to the solution.

Diplomats from around the globe have worked for years in Geneva to devise means to "strengthen" the Biological & Toxin Weapons Convention (BTWC) of 1972, which outlaws BTW. The focus has been on declarations of relevant activities by countries and on inspections of declared facilities. From this essay, it should be clear that BTW facilities can be small, temporary, and without distinguishing features; there is no current means to detect a clandestine BTW production capability, absent serendipitous discovery. Thus, there is no way that the treaty, whether "strengthened" or not, will be able to prevent—or even provide significant obstacles to—clandestine production of biological and toxin agents and weapons. Instead, the proposed treaty changes would actually harm legitimate biotechnology endeavors by creating new expenses and limiting some types of research. Given that arms control does not provide meaningful measures to limit acquisition or use of BTW by nations, groups, or individuals, what can be done to deter and manage consequences of BTW use?

Deterrence is convincing a potential attacker that consequences unacceptable to him will occur if he attacks. The one who deters must not only have the ability and willingness to retaliate, it must clearly communicate both.

Deterring state use of BTW might be possible. This issue is extremely important because BTW are seen as attractive counters to U.S. force for a variety of reasons. First, the United States has no chemical or BTW of its own, having destroyed them in compliance with arms control agreements. This means that any U.S. retaliation is very unlikely to be in-kind. Second, unless a BTW attack against the United States were to cause mass human casualties, it is unlikely, with currently stated U.S. policy, that nuclear retaliation would be used. Third, nations are likely to be aware of the extreme U.S. aversion to troop losses. Thus, the mere possession of BTW in one's arsenal may be enough to deter U.S. intervention abroad. Fourth, it is clear from information in the mass media that U.S. abilities to detect use of BTW, and to vaccinate troops against many agents, is limited.

Iraq is an example of a nation that possessed BTW and was deterred from using them. On more than one occasion, Iraqi leaders have stated that BTW were not used because the Iraqi regime was fearful that the United States would retaliate with nuclear weapons. Thus, there was something that Iraq's leaders held dear—the Iraqi regime—and there was a credible threat—U.S. officials' statements that they reserved the right to retaliate with "overwhelming force" should Iraq use BTW.

Now, however, U.S. deterrence may not work and any future conflict with Iraq might indeed prompt Iraqi use of BTW. On one hand, Iraq has bolstered its defenses against U.S. conventional military capabilities. To assure its own survival, the regime has built deeply buried bunkers and has moved other assets to secure locations. They are no longer very vulnerable to attacks by U.S. missiles and aircraft. While the Iraqi regime would probably fear a U.S. military ground invasion, there are several reasons that this scenario is not very credible, including: the Iraqis are well-aware of U.S. aversion to casualties, they know the United States declined to undertake such a war when it previously had the chance; and they could possibly deter U.S. ground engagement by threatening to use BTW. Given that a ground invasion probably is not a credible retaliatory act by the United States, in Iraqi perception, the U.S. nuclear threat is likely to be the most important asset that could deter Iraq. However, statements by U.S. officials, U.S. media, and U.S. arms control advocates since the Gulf War have offered reassurance to Iraq that the United States would not use nuclear weapons. Regardless of whether this is true, it is the likely Iraqi perception that the U.S. President would not order a nuclear strike. And, it is perceptions that guide action, not necessarily what is true or accurate.

For the U.S. nuclear deterrent to work in the future as it did in the past, the threat of nuclear retaliation must be clearly and convincingly re-articulated. The United States must convey that any Iraqi-sponsored BTW attack of consequence will be met with a nuclear response. Additionally, the United States must assure that it has nuclear weapon designs capable of destroying BTW facilities without causing excessive loss of civilian life. The current U.S. policy of ambiguity regarding nuclear use undermines deterrence by communicating uncertainty on our part.

While nuclear deterrence may work vis-à-vis BTW threats from nations, it will be impotent against terrorists' BTW threats. In the case of suicidal terrorists, deterrence is enormously difficult because there is little that they are likely to hold dear. There is nothing dearer than life, and terrorists like those who struck September 11 are willing to give that for their cause. Methods that may have worked in other nations' efforts to combat terrorism are not likely ever to be used by the United States. Such measures include torture during interrogation, assassinations, murder of families of terrorists, and destruction of terrorists' homes.

The war now being undertaken by the United States against terrorism offers the best opportunity to end support abroad for terrorist groups, and thus diminish the numbers and power of terrorists. But, it is

widely acknowledged, terrorism will not be ended by these efforts. The threat of terrorist use of BTW use against U.S. civilians and military will remain.

This somber analysis is not meant to suggest that the enormous resources being spent to gather intelligence and bring law enforcement to bear on terrorists is not well spent. Finding terrorists before they strike and preventing their vile activities is an extremely high priority deserving of large-scale funding and support. Rather, this discussion is to point out that such efforts and resources cannot, even in the long run, eliminate the threat, particularly that BTW will be used. Thus, it is crucial that we turn to consequence management and determine what can be better done to assure that BTW attacks, if and when they occur, are identified quickly and that their effects are minimized.

In addition to using the U.S. military to root out terrorism and to deter use of BTW, there are other measures that are being undertaken. There are large-scale programs, initiated in the late 1990s, to prepare state and local officials to respond to crises that might involve BTW use. Plans are being implemented to improve rapid medical responses, stockpile medical supplies in strategic locations, and improve the early detection and tracking of disease outbreaks. Funding has been allocated to research vaccines and other prophylactics. State and local agencies are being provided basic equipment and training for responding to chemical or biological incidents. Additionally, law enforcement has been bolstered to address BTW threats. In 1996, the U.S. Congress passed the Antiterrorism and Effective Death Penalty Act of 1996. Pursuant to this law, 175 FBI Special Agents were added to the 56 field offices specifically to work on countering threats from weapons of mass destruction. Undoubtedly, in the aftermath of September 11, additional funding will be made available for all of these preparatory activities and programs.

In the haste and concern to "do something" about the BTW terrorism threat, it will be important to remain focused on efforts that will be most likely to mitigate the problem. Although the measures being undertaken are crucial, there are limits as to what should be done in planning for a BTW emergency. For example, it would not be practical for hospitals to establish many large, expensive, specialized confinement facilities for handling highly contagious patients. These would be overwhelmed in any widespread disease outbreak.

In addition to those steps already being undertaken, the following measures should be considered to improve our chances of withstanding a BTW attack.

1. The United States should undertake BTW research to better understand what is possible in the realm of BTW. Given that there has been no U.S. program since 1969, the U.S. capabilities to analyze foreign BTW activities is limited, as is its ability therefore to develop countermeasures such as vaccines or treatments. Because research for defense could readily be used for offense, the United States must be prepared for criticism that it is violating the BTWC.

2. Smallpox vaccine should be manufactured and administered on a fast track. A $343 million contract for making 40 million doses of vaccine has been awarded by the U.S. Government, with a product due-date of 2004.[42] (The date was moved up to 2002 following September 11.) Because this deadly disease is likely to already be in the arsenals of North Korea, Iraq, and Russia, there should be greater urgency associated with a nationwide vaccination program. Sufficient vaccine should be produced for all citizens, not just the military, leadership, and selected others.

3. On-the-spot tools should be developed to diagnose plant and animal diseases. (High priority is already being given to develop such tools for human diseases.) They must be accurate, quick and not require biocontainment.[43]

4. The Biosafety Level 3 and 4 capabilities of the USDA must be expanded and modernized. Existing BL 4 labs are overtaxed and could not handle farm species if there were a problem.[44]

5. Veterinary science curricula should be revamped to emphasize large-scale animal husbandry, and foreign and exotic disease recognition and treatment.[45]

6. Incentives should be provided to farmers to diversify crops and to intersperse crop types to provide natural barriers against the spread of disease. Similarly, small-scale ranchers should be given incentives in order to help diversify the locations of animal herds.

In conclusion, BTW are horrendous weapons whose damage can range from catastrophic pandemics to economic disasters. They are technologically easy and inexpensive. They can be, and have been, manufactured by individuals, groups, or nations. Until September 11, 2001, there had been no instance of mass destruction of civilian life. With the strike against the World Trade Center and Pentagon, we know that terrorists, perhaps state-sponsored, have passed a threshold; it is now plausible, perhaps inevitable, that BTW will be used in the future. While nations might be deterred from overt use of BTW, terrorist use and covert use by nations remain highly significant threats. The United States must focus anew on steps to understand the technology being employed by those who possess BTW. This means not only that we must undertake research ourselves on BTW agents, we must develop countermeasures. We must also continually reassess what can be done to manage the consequences of BTW attacks. On this latter point, we must focus on BTW threats to agriculture and our economy in addition to those that might harm human life.

Dr. Kathleen Bailey addressed biological weapons in her textbook, *Doomsday Weapons in the Hands of Many* (Westview Press, 1991) and in her novel, *Death for Cause* (Meerkat, 1995).

Endnotes

[1] K.F. Gensheimer, et al, "Preparing for Pandemic Influenza: The Need for Enhanced Surveillance," *Emerging Infectious Diseases*, Vol. 5, No. 2 Mar-Apr 1999, p. 297.

[2] Foot-and-mouth disease is the most infectious viral disease known. It can spread over 170 miles as an aerosol and one infected animal releases enough virus in one day to theoretically infect 100 million cattle.

[3] Peter Chalk, "The Political Terrorist Threat to US Agricultural and Livestock," (Paper presented at a workshop on "Agro-Terrorism: What is the Threat?" at Cornell University, 12 November 2000), pp. 11, 13.

[4] Horn & Breeze, "Agriculture and Food Safety," in Thomas Frazier and Drew Richardson, eds., *Food and Agricultural Security: Guarding Against Natural Threats and Terrorist Attacks Affecting Health, National Food Supplies, and Agricultural Economics*, Vol. 894 (New York: Annals of the New York Academy of Sciences, 1999), p. 14.

[5] Peter Chalk, op. cit., footnote 3, p. 18.

[6] Anti-material agents are organisms that degrade items such as fabrics, rubber, leather and metal. For example, some bacteria produce highly acidic compounds that cause pitting in metals, which could cause problems with stockpiled materiel. See Lester C. Caudle, "The Biological Warfare Threat," in Office of the Surgeon General, U.S. Army, *Medical Aspects of Chemical and Biological Warfare*, 1997, p. 4.

[7] Weapon of Mass Destruction (WMD) type cases, primarily those cases dealing with the threatened use or procurement of chemical and biological materials with intent to harm, have steadily increased. In 1996, 37 cases were opened by the FBI. In 1997, there were 74 cases opened, of which 22 were related to biological agents. By 1998, the FBI opened 181 cases, 112 of which were biological in nature. By mid-1999, there had been 123 WMD cases, 100 of which were biological. In 1998 and 1999 combined, over three-quarters of the cases opened have threatened a biological release, and the biological agent most often cited in 1998 and 1999 has been anthrax. See Robert M. Burnham, Chief of Domestic Terrorism Section, Federal Bureau of Investigation, Testimony before the U.S. House of Representatives, Subcommittee on Oversight and Investigations, 19 May 1999.

[8] Biological agents are either replicating agents (bacteria or viruses) or nonreplicating materials (toxins or physiologically active proteins or peptides) that can be produced by living organisms. Some nonreplicating biological agents can also be produced through either chemical synthesis, solid-phase protein synthesis, or recombinant expression methods. Office of the Surgeon General, U.S. Army, *Medical Aspects of Chemical and Biological Warfare*, 1997, p. 4.

[9] This discussion of types of agents is drawn in part from U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, (Washington, D.C.: U.S. Government Printing Office, December 1993), pp. 79-81.

[10] Barry J. Erlick, Testimony before the U.S. Senate Committee on Governmental Affairs, February 9, 1989 (Washington D.C.: U.S. Government Printing Office, 1990), P. 32, as cited *in Technologies Underlying Weapons of Mass Destruction*, p. 78.

[11] Although *Coxiella burnetii* is classified in the family Rickettsiae, it is not included in the genus Rickettsia. The genus *Coxiella* has only one species.

[12] Caudle, op. cit., footnote 6, p. 461.

[13] Prions are proteinaceous infectious particles that lack nucleic acids. They are composed of an abnormal isoform of a normal cellular protein. Although there is no evidence of aerosol transmission of prions from one human to another, there are examples of transmission among humans under some circumstances, e.g., cannibalism in New Guinea causing kuru. See Jiri Safar, et al, "Agent Summary Statements Section VII-D: Prions," in *Emerging Infectious Diseases* at http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4s7d.htm. There is the possibility that prion diseases can be transmitted from persons who appear healthy, but who are incubating the diseases, through surgical and medical diagnostic procedures or through blood transfusions. See Paul Brown, et al, "Bovine Spongiform Encephalopathy and Variant Creutzfeldt-Jakob Disease: Background, Evolution, and Current Concerns," *Emerging Infectious Diseases*, Vol. 7, No. 1, January-February, 2001, p. 6.

[14] Chalk, op. cit., footnote 3, p. 11.

[15] Options by which BSE could be introduced into U.S. beef and dairy cattle are discussed in Paul Brown, "Afterthoughts about Bovine Spongiform Encephalopathy and Variant Creutzfeldt-Jakob Disease," *Emerging Infectious Diseases*, Vol. 7, No. 3, Supplement 2001, pp. 598-99.

[16] U.S. Government, *The Biological and Chemical Warfare Threat*, Revised Edition 1999, (Washington D.C.: U.S. Government Printing Office), p. 3.

[17] Of the 395 toxins known to U.S. Government officials, only 17 would make useful battlefield weapons because they are relatively stable and can be readily manufactured in large quantities. Seventy-three would be toxic enough to be used in an enclosed space such as the air handling system of a building or an aircraft carrier, or on a street corner during rush hour. See David Franz, Deputy Commander USA Medical Research and Materiel Command, Testimony before the U.S. Senate Joint Committee on Judiciary and Intelligence, 4 March 1998.

[18] Judith Miller, "Next to Old Rec Hall, a 'Germ-Making Plant'," *The New York Times*, 4 September 2001, <http://www.nytimes.com/2001/09/04/international/04BIOW.html>.

[19] *Technologies Underlying Weapons of Mass Destruction*, p. 32.

[20] Insects themselves, although they can be enormously destructive, are not included in the definition of biological weapons. Nevertheless, they can be used as weapons against a nation's economy. There has been speculation, for example, that the appearance in the late 1980s of the Mediterranean fruit fly in California was the result of sabotage. See Caudle, op. cit., footnote 6, p. 4.

[21] Piers D. Millett and Simon M. Whitby, "State Agro-Biological Warfare Programmes," Paper presented at conference on "Agro-Terrorism: What Is The Threat?", held at Cornell University, Ithaca, New York on 12-13 November 2000, p. 3.

[22] Committee on Armed Services, House of Representatives, "Countering the Chemical and Biological Threat in the Post-Soviet World," (Washington D.C.: U.S. Government Printing Office, 23 Feb 1993).

[23] Kenneth Alibek, "The Soviet Union's Anti-Agricultural Biological Weapons," in Thomas Frazier and Drew Richardson, eds., *Food and Agricultural Security: Guarding Against Natural Threats and Terrorist Attacks Affecting Health, National Food Supplies, and Agricultural Economics*, Vol. 894 (New York: Annals of the New York Academy of Sciences, 1999), p. 18.

[24] To give a perspective on the enormity of the program, the U.S. Department of Agriculture's Agricultural Research Service has some 7,000 scientists and technicians to address all agricultural research issues from air quality to catfish genetics. See Horn & Breeze, op. cit., footnote 4, p. 10.

[25] Judith Miller, "US Aid Is Diverted To Germ Warfare, Russian Scientists Say," *The New York Times*, 25 January 2000,<http://www/nytimes.com/2000/01/25/national/012500germ.html>.

[26] Caudle, op. cit., footnote 6, p. 454.

[27] Judith Miller, Stephen Engelberg, and William Broad, "US Germ Warfare Research Pushes Treaty Limits," *The New York Times*,4 September 2001 <http://www.nytimes.com/2001/09/04/international/04GERM.html>.

[28] A 1999 U.S. intelligence report cited Russia, Iraq, and North Korea as having smallpox virus weapons. See William J. Broad and Judith Miller, "Government Report Says 3 Nations Hide Stocks of Smallpox," *The New York Times*, 13 June 1999, <http://www.nytimes.com/1999/06/13/international/061399germhtml>.

[29] Miller, op. cit., footnote 25.

[30] Letter dated 8 April 1998 from the Executive Chairman of the Special Commission to the President of the UN Security Council, S/1998/308.

[31] Tim Youngs and Mark Oakes, "Iraq: 'Desert Fox' and Policy Developments," Research Paper 99/13, 10 February 1999, UK House of Commons Library, p. 26.

[32] Broad & Miller, op. cit., footnote 28.

[33] Many of these examples are outlined in a Working Paper by Seth Carus viewable at the Web site for the National Defense University. The description herein of the example of the Rajneeshees is drawn from Carus' Working Paper.

[34] This account of Aum Shinrikyo's activities is taken from Seth Carus, Testimony before U.S. Senate, Joint Hearing of the Select Committee on Intelligence and the Judiciary Committee Subcommittee on Technology, Terrorism and Government Information, 4 March 1998.

[35] The genus *Clostridium* has organisms that have been classified into the equivalent of six species, four of which are designated as groups I-IV of *Clostridium botulinum*. The toxins produced by these organisms vary and are differentiated as types A, B, C, D, E, F, and G. The toxins vary in the severity of their effects. Human botulism is caused predominantly by organisms from groups I and II, while avian and animal botulism is principally a result of group III organisms. See Charles L. Hatheway, "*Clostridium botulinum* and Other Clostridia that Produce Botulinum Neurotoxin," in Andreas Hauschild and Karen Dodds, *Clostridum botulinum: Ecology and Copntrol in Foods*, (New York: Marcel Dekker, Inc., 1993), pp. 5, 15-16. Thus, the Aum Shinrikyo scientists could have purposefully or inadvertently selected an organism whose toxicity was ineffective against human targets.

[36] Millett and Whitby, op. cit., footnote 21, p. 8.

[37] Horn & Breeze, op. cit., footnote 4, p. 13.

[38] For scenarios involving terrorist attacks with biological weapons against U.S. agriculture and other targets, see the novel *Death For Cause* by K.C. Bailey (Danville, CA: Meerkat Publications, 1995).

[39] Javier Ekboir, *The Potential Impact of Foot and Mouth Disease in California: The Role and Contribution of Animal Health Surveillance and Monitoring Services* (Davis, CA: Agricultural Issues Center, 1999), pp. 26, 29, as cited in Chalk, op. cit., footnote 3, p. 4.

[40] Millett & Whitby, op. cit., footnote 21, p. 8.

[41] Conversation between Peter Chalk and USDA official Tom Walton, as cited in Chalk, op. cit., footnote 3, p. 5.

[42] William Broad and Melody Petersen, "Defense May Be Inadequate for Germ or Toxic Attacks," *The New York Times*, 23 September 2001 <http://www.nytimes.com/2001/09/23/national/23GERM.html>.

[43] This recommendation is made by Horn & Breeze, op. cit., footnote 4, p. 15.

[44] Ibid.

[45] Chalk, op. cit., footnote 3, p. 24.