

## 2. THE CHARACTER OF CBW THREATS

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– Chemical and Biological	
– Delivery Options	
– When Might Threats Materialize?	
• Possible Solutions	
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This section addresses the characteristics of potential chemical and biological threats to U.S. Air Force operations, along with possible delivery modes for these threats. The section ends with a short discussion of when these threats might materialize.

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The chemical and biological threats are discussed first.

<b>CBW Effects Depend On...</b>
<ul style="list-style-type: none"> <li>• <b>Character of the Agent</b> <ul style="list-style-type: none"> <li>- Toxicity</li> <li>- Nature of the effect</li> <li>- Mode of entry into humans; human activity levels</li> <li>- Persistence</li> </ul> </li> <li>• <b>Meteorological conditions</b> <ul style="list-style-type: none"> <li>- Wind speed</li> <li>- Atmospheric stability (&amp; inversion layers)</li> <li>- Temperature</li> <li>- Humidity</li> <li>- Sunlight</li> </ul> </li> <li>• <b>Weapon delivery mode</b> <ul style="list-style-type: none"> <li>- Amount of agent</li> <li>- Altitude of release</li> <li>- Dissemination efficiency</li> </ul> </li> </ul>
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The lethality of chemical and biological weapons depends on numerous factors, grouped here according to the character of the agent, meteorological conditions, and the weapon delivery mode. Together, these factors cause the lethal areas of different CBW agents to vary by many orders of magnitude.

## **THE CHARACTER OF CBW AGENTS**

The toxicity of chemical agents varies by a factor of about 100 over the range of common agents. Biological agents' toxicity varies by four orders of magnitude. Moreover, the exact toxicological effects of specific agents on human beings frequently are unknown to within a factor of two or more, because most of the data come from animal experiments. These data are then extrapolated to humans. To complicate matters further, different CBW agents have different effects. Some are lethal; others are merely incapacitating. But even incapacitating effects can affect military operations.

The mode of entry into the human body affects the toxicity of a given agent. CBW agents are the most toxic when inhaled into the lungs. Chemical agents are less toxic when absorbed through the skin. In addition, chemical agents may be absorbed through the eyes (causing miosis) and other mucous membranes. Biological agents are typically lethal only when inhaled. Particles in the 1- to 10- $\mu\text{m}$  (micron) range are

most dangerous, because smaller particles tend to be exhaled and do not stay in the lungs. Particles larger than 10  $\mu\text{m}$  are likely to be blocked before reaching the lungs. Respiratory doses of chemical or biological agents depend on the breathing rate and, hence, on the level of human activity. Personnel engaged in heavy work will absorb a toxic dose sooner than personnel engaged in light work.

CBW agents can enter the body through the intestinal tract from contaminated food or water. While these are potential threats, the attacker must be sure the biological agent is resistant to heat if the food has yet to be cooked or is resistant to water treatment (e.g., chlorine) if the water is treated. Moreover, it may be difficult to place biological agents, perhaps repeatedly, into the base food supply without being noticed. As a result, some analysts believe these are less important threats. No systematic attempt was made to analyze these threats in this study.

Finally, some chemical agents persist on the ground for long periods of time, thereby presenting a contact and/or vapor hazard long after the attack. Chemical persistence depends on the vapor pressure of the agent, the temperature, and the wind speed. Biological agents, on the other hand, are nonvolatile—but those that can form spores may remain active for a long time in the soil. If re-aerosolized (e.g., by jet exhaust), they can become a hazard.

## **METEOROLOGICAL CONDITIONS**

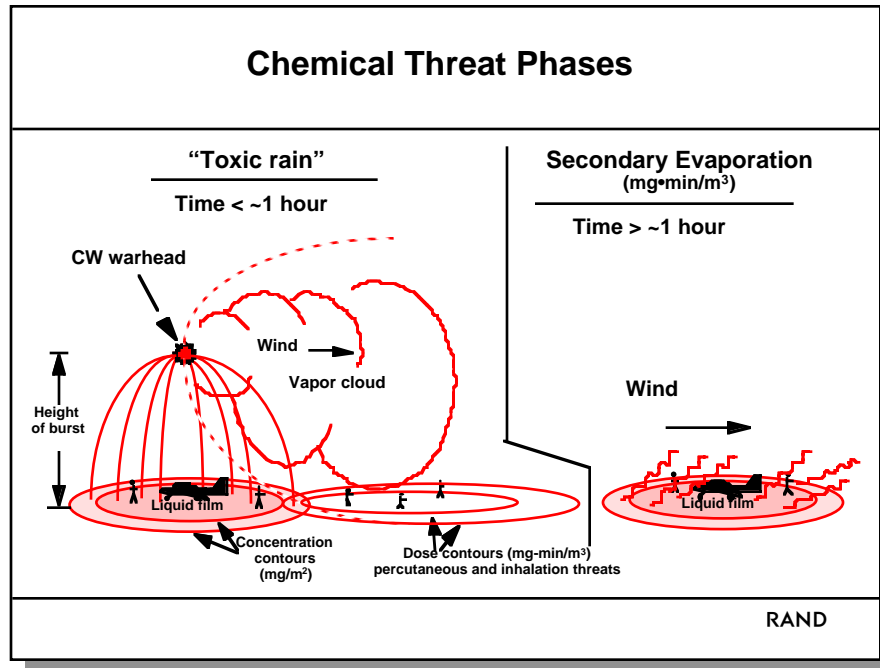
Meteorological conditions cause the size of CBW-contaminated areas to vary by a factor of 10–100 or more. Moreover, many of these factors are difficult to predict in advance, making the adversary's calculation of weapon effects difficult. The most important variables are wind speed, wind direction, atmospheric stability (including the presence or absence of an inversion layer), temperature, humidity, and the level of sunlight. For example, humidity causes chemical agents to hydrolyze (depending on the pH of the water vapor), thus reducing their toxicity downwind from the dispersal point, and sunlight kills or denatures most biological agents, making nighttime dispersal almost mandatory.

## **WEAPON DELIVERY MODE**

Finally, the mode of delivery affects the lethal area of a given attack. Payload is an obvious variable and can vary by an order of magnitude or more for different aircraft, unmanned aerial vehicles, ballistic missiles, and SOF attacks. There is also the issue of release altitude. If the chemical

weapons (CW) agent is released too high, it will be too dilute when it reaches the ground. If it is released too low, the lethal area will be smaller. Altitude is important, because if biological or nonpersistent chemical agents are dispersed above an inversion layer, little of the aerosol particles or gas will reach the ground. On the other hand, if the weapon is detonated below an inversion layer, the ground concentrations may be twice what they otherwise would have been, because the CBW cloud reflects off the inversion layer. Thus, the altitude of any inversion layer has a significant impact on the effectiveness of a CBW attack, as well as on the altimeters required on the delivery systems.

Dissemination efficiency for biological agents refers to the efficiency with which the agent is dispersed into a fine aerosol, 1 to 10  $\mu\text{m}$ . Biological agents dispersed by a unitary explosive charge are relatively inefficient (resulting in approximately a few percent of the agent being 1 to 10  $\mu\text{m}$ ). Spray nozzles that atomize biological agents can inject approximately 50 percent or more of the agent as 1- to 10- $\mu\text{m}$  particles, thereby increasing the effective payload by an order of magnitude. Therefore, to determine the lethal area associated with a given attack, one must make assumptions about the adversary's dispensing technology.



## CHEMICAL THREATS

This subsection discusses the technical aspects of chemical threats. The above chart illustrates the two phases of a chemical attack, the “toxic rain” phase and the secondary evaporation phase. The toxic rain phase occurs when the liquid agent rains onto the ground from the point of detonation. This phase lasts a relatively short time (~1 hr) and has two parts: a liquid film and a vapor cloud. The amount of agent deposited on the ground as a thin liquid film and the amount carried downwind as a vapor depend on the dispersal mechanism and the volatility of the agent. The finer the mist and the more volatile the chemical agent, the greater the downwind concentration of the toxic cloud.

The toxic rain phase creates two problems for the defender. First, anyone who gets rained upon while outdoors or who comes into contact with the liquid film after it deposits on the ground encounters a contact hazard. At high concentration (measured in  $\text{mg}/\text{m}^2$ ), lethal doses can be delivered through exposed skin. The vapor cloud blowing downwind presents either a respiratory threat, if personnel inhale the toxic vapors, or a percutaneous threat, if the vapor is absorbed through the skin. Either mode of entry can incapacitate or kill the exposed individual depending on the dose (measured in  $\text{mg}\cdot\text{min}/\text{m}^3$ ). Even relatively low concentrations of vapor, if they come in contact with the eyes, can cause

ocular damage (e.g., miosis from nerve agents). The dosage received downwind depends on the amount of time the individual stands in the vapor cloud. Respiratory effects also depend on the breathing rate. Obviously, the dose received depends critically on whether protective gear is worn. Gas masks and protective overgarments greatly reduce the dose the body actually receives, as will be discussed.

After a period of several hours, the initial vapor cloud has blown some distance downwind and has dissipated because of atmospheric diffusion. Eventually, it becomes sufficiently attenuated so that it no longer represents a threat. The liquid film, on the other hand, may persist for hours, days, or weeks depending on the volatility of the agent, the type of surface, and atmospheric conditions (principally temperature and wind speed). The liquid film continues to present a contact hazard for anyone touching the contaminated surface. Moreover, in hot weather, the liquid film of a persistent agent, such as VX, can evaporate fast enough to create a substantial secondary vapor threat. This is the second problem that deserves careful scrutiny, because it represents a long-term threat to military operations at such facilities as ports and air bases.

Thus, when analyzing the impact of chemical attacks, one must take into account the initial toxic rain phase and the effects from secondary evaporation.

<b>Approximate Chemical Agent Toxicity</b>				
	Liquid "Hazard" (mg/m <sup>2</sup> )	Vapor Challenge <sup>1</sup> (mg-min/m <sup>3</sup> )		
		LCT <sub>50</sub>	ICT <sub>50</sub>	OCT <sub>thres.</sub>
• Choking agents				
– Phosgene (CG): respiratory		3200	1600	
• Blistering agents				
– Mustard (HD): respiratory		900	450	
– Mustard (HD): percutaneous <sup>2</sup>	~700	1,500	750	60
• Blood agents				
– Hydrogen cyanide (AC)		2,000-4,500	varies	
• Nerve agents				
– Tabun (GA): respiratory		270	200	
– Tabun (GA): percutaneous <sup>2</sup>	~50	30,000	15,000	2.5
– Sarin (GB): respiratory		35	20	
– Sarin (GB): percutaneous <sup>2</sup>	~170	10,000	5,000	1.5
– Soman (GD): respiratory		70	35	
– Soman (GD): percutaneous <sup>2</sup>	~15	10,000	5,000	0.2
– VX: respiratory		15	8	
– VX: percutaneous <sup>2</sup>	~0.5	150 <sup>2</sup>	75	0.06

SOURCE: FM 3-9; ERDEC-SP-018.  
Notes: <sup>1</sup> mild activity,  
<sup>2</sup> bare skin

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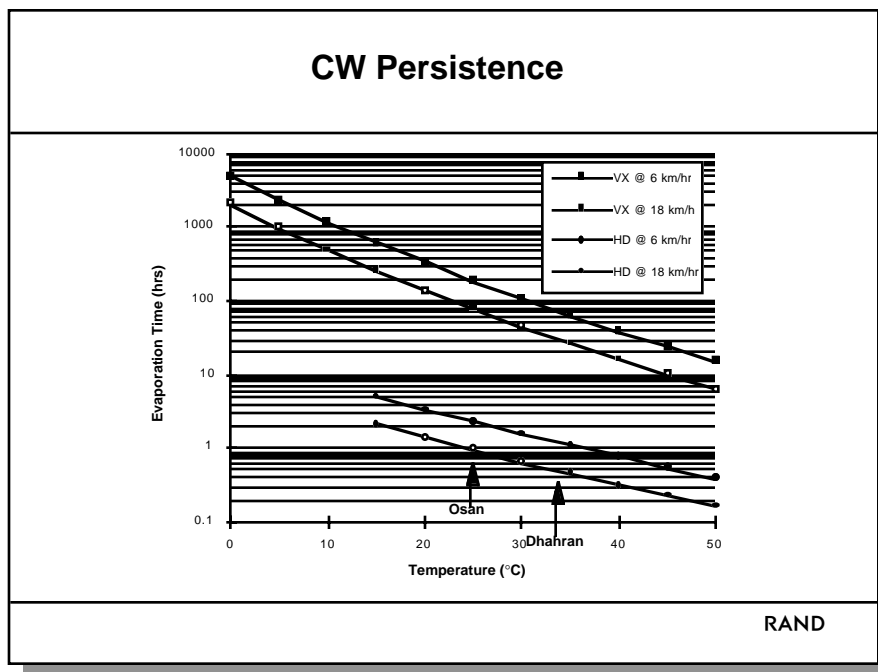
This chart illustrates standard incapacitating and lethal doses for a range of typical chemical agents. The agents are categorized according to whether they are choking agents, blistering agents, blood agents, or nerve agents. Nerve agents tend to be the most toxic and typically represent the worst-case chemical threats. The numbers under the liquid "hazard" column represent the levels of liquid film that constitute a significant hazard to unprotected ground personnel. A "significant" hazard is assumed here to be 1/10 of a lethal dose for a naked person. In other words, if a person came into contact over a period of days with 10 m<sup>2</sup> contaminated to this level, he or she would receive a lethal dose through the skin. While 10 m<sup>2</sup> sounds like a large area, it is not if one comes into contact with contaminated surfaces repeatedly day after day. Therefore, liquid "hazard" is defined to be a hazard level that would require ground personnel to wear gloves and outerboots to avoid incapacitating or lethal effects through contact with the liquid film.

The vapor challenge numbers represent lethal and incapacitating doses for the various agents and the estimated thresholds for ocular effects. The vapor can come from the initial vapor cloud or secondary evaporation. The nerve agents are the most lethal. The respiratory hazard from VX is two orders of magnitude more toxic than phosgene, mustard, or hydrogen cyanide. Incapacitating doses (measured in Incapacitating Concentration Time, ICT) tend to be about half of the lethal dose (measured in Lethal Concentration Time, LCT) for many chemical agents. Similarly,

percutaneous doses typically are 10–100 times higher than the respiratory doses, with the exception of blister agents, such as mustard. In short, inhalation is by far the most lethal mode of exposure for most chemical agents.

Ocular effects have the lowest dose—typically occurring at doses (OCT threshold) on the order of 10 to 100 times lower than those resulting in respiratory incapacitating or lethal effects.

This chart does not indicate which of the agents are persistent. Mustard is a classic persistent agent, along with VX (which is even more persistent). Tabun is reasonably persistent, and soman frequently is thickened to increase its persistence. Sarin is a typical nonpersistent nerve agent. In general, worst-case chemical threats frequently use sarin for a nonpersistent agent and VX for a persistent agent. Mustard, although less toxic, may also be a serious threat because of its incapacitating effects.



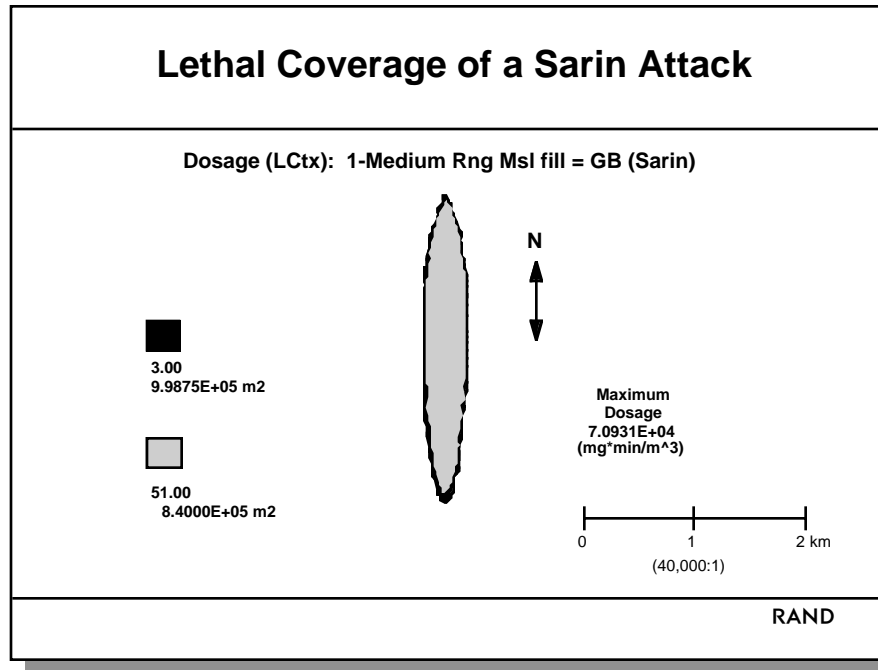
NOTE: A full-size version of this chart can be found in Appendix B.

The persistence time for CW agents depends principally on the droplet size, temperature, wind speed, and character of the surface. The two upper curves show the 90-percent evaporation time for VX under two wind conditions over a range of temperatures from 0 to 50°C. The surface is assumed to be grass. The average summer temperature in Osan, Korea, is approximately 25°C and in Dhahran, Saudi Arabia, is around 34°C. Thus, depending on the wind speed, VX would last anywhere from 100 to 200 hours at Osan (4–8 days) or between 30 and 60 hours at Dhahran (1–3 days) in the summer.<sup>1</sup> Under cool, calm atmospheric conditions, VX could last for a month or more. It should be noted that although VX could last for months, its rate of secondary evaporation could be so low that wearing only a mask (but not a suit) will suffice. Therefore, an adversary might prefer a higher temperature and shorter persistence so that the evaporation is high enough to force our troops into wearing the full suit for maximum performance degradation. Mustard has a shorter persistence time, as indicated by the lower two curves. Under summer

<sup>1</sup>Since the average wind speed in Korea is closer to 6 km/hr than to 18 km/hr, VX persistence should be closer to eight days than to four days. On the other hand, since the average wind speed in the Persian Gulf is closer to 18 km/hr, the persistence is closer to one day than to three days.

conditions, mustard would last around 1 to 2.5 hours at Osan, depending on the wind speed, and only a fraction of an hour to an hour at Dhahran. At 15°C, mustard freezes. Hence, the persistence curves would become steeper (not shown in the figure), because sublimation is slower than evaporation.

The basic point is that the persistence of chemical agents varies widely and depends heavily on the weather. CW persistence time must be taken into account to assess fully the effectiveness of chemical attacks on military facilities.



NOTE: A full-size version of this chart can be found in Appendix B.

Having listed the various agents, we now turn to the lethal area of a chemical attack. An adversary has two tactics. First, he wants to catch our troops by surprise. If U.S. personnel are not in mission-oriented protective posture (MOPP) gear, the lethal dosage is the much lower respiratory dosage, as opposed to the much higher percutaneous dosage. An adversary would use a highly volatile chemical agent such as sarin for the attack. Second, if U.S. personnel are not in MOPP gear before the first chemical attack, they should be in it after the first attack. Then, an adversary might want to keep our crews in full MOPP gear (wearing not only the mask, but also the much more burdensome suit) in order to degrade their performance. It would likely use persistent chemical agents such as VX for follow-on attacks.

Let us discuss a surprise sarin attack first. The lethal coverage of sarin depends on the amount of agent, temperature, wind speed, and many other factors. Above we see a case of 500 kg of sarin carried by a Scud missile. The temperature is 25 degrees centigrade,<sup>2</sup> the wind speed is 2 km/hr (light air, drifting smoke, but stationary wind vanes), the height of burst is optimal, and the atmosphere is at neutral stability (Pasquill

<sup>2</sup>The monthly mean temperature is above 30°C from May to September in Dhahran and is above 20°C from March to November in Dhahran and June to September in Osan.

Stability Category D) and overcast. In the chart, LCT is the dosage or the vapor concentration of the agent multiplied by the time of exposure.  $LCT_{50}$  is the dosage that is lethal to 50 percent of exposed, unprotected people at some given breathing rate. The chart shows the contours for  $LCT_{51}$ <sup>3</sup> and  $LCT_3$ . Also shown are the areas within the contours. The dosage inside the contour would be greater than that on the contour. Thus, 0.8 km<sup>2</sup> of the area would have dosage equal to or greater than the dosage that is lethal to 51 percent of the personnel. Similarly, 1.0 km<sup>2</sup> of the area would have a dosage lethal to 3 percent of the personnel or more. Because a typical airfield is 4 km<sup>2</sup> (1 km by 4 km), several missiles will give a significant coverage. The precise number will be discussed later.

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<sup>3</sup>The reason for using 51 percent instead of 50 percent will be explained in the text for the next chart on *VX Dosage That Calls for the Wearing of MOPP Gear*. In any case, the two percentages are close enough to be considered the same.

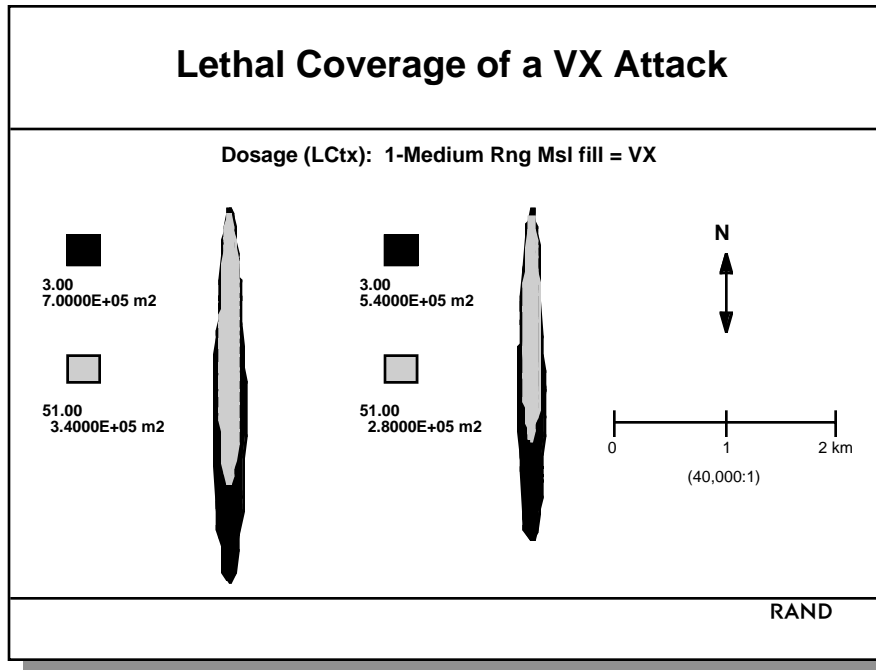
<b>VX Dosage That Calls for the Wearing of MOPP Gear</b>	
	<b>Dosage (mg-min/m<sup>3</sup>)</b>
<b>LCT<sub>50</sub> respiratory, 12 hrs</b>	<b>15</b>
<b>LCT<sub>50</sub> percutaneous, bare skin to fully clothed</b>	<b>150–300</b>
<b>LCT<sub>5</sub> percutaneous</b>	<b>75–150</b>
<b>LCT<sub>5</sub> percutaneous per day</b>	<b>7.5–15</b>
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On subsequent days, base personnel are assumed to be in protective gear. Hence, the opponent's objective shifts to keeping U.S. base personnel in a protected posture in the hope of slowing down the operational tempo at the base and, hence, having an indirect impact on U.S. military capability (e.g., sortie-generation capability or airlift throughput). Persistent chemicals are most effective for forcing U.S. forces into MOPP gear. Below, we will show that the relevant daily percutaneous dosage is about the same as the respiratory LCT<sub>50</sub>, which is 15 mg-min/m<sup>3</sup> for the case of VX.<sup>4</sup> First, we assume that the percutaneous dosage for bare skin is 10 times that of the respiratory dosage, and that the percutaneous dosage for a fully clothed person is yet another factor of two higher. This translates into a percutaneous LCT<sub>50</sub> of 150 to 300 mg-min/m<sup>3</sup>. Second, a base commander is assumed to want very low casualties among base personnel. Hence, from the base commander's perspective, doses at the percutaneous LCT<sub>5</sub> or LCT<sub>1</sub> level represent threats, instead of LCT<sub>50</sub>.<sup>5</sup> This results in a percutaneous LCT<sub>5</sub> of 75 to 150 mg-min/m<sup>3</sup>. Third, there are large uncertainties about how the dose will accumulate in one's body

<sup>4</sup>To be precise, the daily percutaneous dosage that is lethal to 5 percent of the personnel (wearing masks but not protective clothing) is the same as the respiratory LCT<sub>51</sub> (not wearing masks). But 51 percent and 50 percent can be considered to be the same.

<sup>5</sup>Alternatively, one may choose ICT levels as criteria.

over time. We assumed the dose is cumulative over a period of ten days. Therefore, personnel should not receive more than one-tenth of the clothed, percutaneous LCT<sub>5</sub> dosage in one day, or 7.5 to 15 mg-min/m<sup>3</sup>. Finally, we assume workers will be exposed to contamination for only 12 hours a day and that they will be in protective shelters for the other 12 hours. If the lack of sufficient shelters continues, the lethal percutaneous dosage could be only half as much as the estimates here.



NOTE: A full-size version of this chart can be found in Appendix B.

If after the first attack our troops are still not wearing masks, sarin (as well as biological agents such as anthrax, to be discussed later) will be the agent of choice. On the other hand, if our personnel are now in protective gear, it is better to use a persistent agent such as VX. It is less volatile, but its liquid could stay on the ground and produce secondary evaporation for days.

VX lethal coverage (for the plume at the left of the chart) is only 0.3 km<sup>2</sup>,<sup>6</sup> so a few (say, three) missiles will have to be used to cover a significant fraction of an air base. Although VX has a small lethal coverage, it only shrinks a little after one day (plume at right of the chart), while the effect from nonresistant agents such as sarin would have long vanished. Even at a temperature of 25° C, the plume can remain sizable for about 3 days. Thus, using (say) three VX missiles every three days can have a significant and continuous lethal coverage over an air base. It averages to one VX missile per day.

<sup>6</sup>Assuming the same payload and weather conditions as the sarin case. The VX lethal coverage refers to respiratory LCT<sub>51</sub> or daily percutaneous LCT<sub>5</sub>, as discussed in the previous chart.

The VLSTRACK model with rapid approximation was used to calculate the lethal areas in this briefing.<sup>7</sup> However, these areas can vary greatly, depending on which model or approximation is used. We have compared VX and sarin results from the VLSTRACK model with those from HAVN4<sup>8</sup> and found the results sometimes differ by one to two orders of magnitude. Sarin results within the VLSTRACK model tend to be similar for the rapid approximation and the rigorous computation, whereas VX results can differ by two orders of magnitude or more. The reason that we used the numbers from VLSTRACK with the rapid approximation here is because they are closer to the HAVN4 results than those from the rigorous computation. Moreover, the VLSTRACK runs we used here are also consistent with our estimates based on the methodology developed by Chinn.<sup>9</sup> It is important to obtain more experimental data and to validate models with existing and new data.

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<sup>7</sup>Timothy Bauer and Roger Gibbs, *Software User's Manual for the Chemical/Biological Agent Vapor, Liquid, and Solid Tracking (VLSTRACK) Computer Model*, Version 1.6, February 1995, and Version 1.6.1, October 1995, Naval Surface Warfare Center. The rapid approximation and the rigorous computations are used to calculate the rate and effects of secondary evaporation for chemical agents. Secondary evaporation is irrelevant for biological agents, because they are nonvolatile.

<sup>8</sup>In June 1993, Jerry Jensen, Eric Brunswick, and Clyde Replogle, at the Armstrong Laboratory, used HAVN4 (High Altitude Variable NUSSE, version 4) to calculate the effects for a large number of runs. NUSSE is the Non-Uniform Simple Surface Evaporation Model. We have compared some of their HAVN4 results with those from VLSTRACK under similar conditions.

<sup>9</sup>Kenneth Chinn, U.S. Army Dugway Proving Ground, June 1981.

## General Properties of Biological Agents

- **Highly Toxic**
  - $10^2$  to  $10^8$  times more toxic than chemical nerve agents
  - Some agents can be used for nonlethal attacks
- **Nonvolatile**
- **Slight percutaneous effect**
- **Slow acting**
- **Most agents decay rapidly in the air**

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## BIOLOGICAL THREATS

This subsection addresses biological weapon threats. Biological warfare agents are either living organisms or poisonous substances produced by living organisms (i.e., toxins). The living organisms can be bacteria, viruses, or fungi. Bacteria are the most common biological warfare agents. Less common are viruses, although they may become more common in the future. Fungi, generally, have not been important biological agents. Another class of biological agents, rickettsiae, is now thought to be a form of bacteria.

The main attraction of biological agents is their high toxicity—on the order of  $1 \times 10^2$  to  $1 \times 10^8$  times more potent than nerve agents, the most potent chemical agents—because they grow once they are in the human body. In addition, the Air Force currently has no capability to detect or identify biological agents in the air.<sup>10</sup> Hence, tactical warning and attack assessment are generally not possible.

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<sup>10</sup>The U.S. Army is beginning to deploy the Biological Integrated Detection System (BIDS), which can detect and identify attack in about one-half hour. The U.S. Air Force prefers to use the Navy's Biological Agent Detection System (BADs) (now called Joint Biological Point Detection System) because it is more automated than BIDS, but unfortunately BADs will not be available until 2002. In the meantime, if the biological warhead is carried by a ballistic missile, the Air Force can obtain tactical warning from

On the other hand, biological agents are nonvolatile. Thus, the agent does not evaporate once it hits the ground, although modest surface activity can reintroduce the agent into the air to some extent. Moreover, the nonvolatility of biological agents constrains their release altitude. Either the weapon must detonate on the ground (i.e., be contact fused), sending perhaps half of its payload into the air, or it must detonate low enough to have lethal concentrations diffuse to the ground. If the detonation altitude is too high (e.g., above 0.5 km), a higher fraction of the agent may decay in the air; by the time the agent diffuses to the ground, the ground-level concentrations may be too low to have much effect. Hence, nondestructive contact bursts or accurate altimeters are required to deliver biological agents effectively.

In addition, biological agents have little percutaneous effect, although some biological agents may be harmful if ingested or if they enter the body through breaks in the skin (e.g., cuts or wounds). Moreover, many biological agents have relatively long incubation periods, usually taking days to weeks before the desired effect occurs.<sup>11</sup> Some toxins, such as Staphylococcal enterotoxin-B (SEB), however, have incubation periods as short as hours. Finally, most biological agents, with some important exceptions, decay rapidly once dispersed—either because they dehydrate, because ambient ultraviolet light kills them (especially in the daylight), or because other environmental effects take a toll.

The fact that biological agents are not always lethal may actually be an advantage. Attacks that kill thousands of innocent civilians will likely draw a strong U.S. (and international) response, which may make adversaries wary about using biological (or chemical) weapons near populated areas. On the other hand, nonlethal biological attacks may accomplish their military purpose, e.g., shutting down operations at an airfield or port, while at the same time avoiding high civilian, as well as military, fatalities.

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the launch of the missile itself. If the agent is spread by SOF or a cruise missile, tactical warning might not be available.

<sup>11</sup>The incubation period is the time it takes before the effects of the agent are observed in an infected population.

Characteristics of Key Biological Agents							
Agent	ECt50 (mg-min/m <sup>3</sup> )	Mortality (%)	Nighttime aerosol decay rate (%/min)	Incubation Period (Days)	Contagious	Antibiotic	Vaccine
<b>Bacteria</b>							
Anthrax	5x10 <sup>-4</sup>	100	0-0.1	1-6	No	Yes	Yes
Plague	5x10 <sup>-4</sup>	100	10	2-3	Yes	Yes	Yes?
Tularemia	5x10 <sup>-6</sup>	5-60	5	2-10	No	Yes	Yes
Q Fever	1x10 <sup>-6</sup>	0-1	0-0.1	10-21	No	Yes	Yes
<b>Toxins</b>							
Bot Tox	5x10 <sup>-2</sup>	100	5	0.5-1	No	No	Yes*
SEB	0.1-1	0	1	1-6 hr	No	No	No
<b>Viruses</b>							
Smallpox	5x10 <sup>-3</sup>	15-40	0.5	7-21	Yes	No	Yes
<b>Fungi</b>							
* Non-FDA approved							RAND

NOTE: A classified version of this table and its annotation is contained in a separate volume.

This chart provides an overview of the important characteristics of some of the key biological agents. One should bear in mind that the numbers in this table are uncertain, perhaps by a factor of 10 or more. The ECT<sub>50</sub> is a measure of the dose at which 50 percent of the population experiences the agent's primary effect (incapacitation or death). The mortality gives the percent of the infected population that typically dies. The nighttime aerosol decay rate is the rate at which the agent loses effectiveness if dispersed at night. Daytime decay rates are much higher because of the effects of ultraviolet light—limiting most biological attacks to nighttime. The incubation period is typically measured in days, with the exception of SEB. The next three columns indicate whether the agent is contagious; whether antibiotics are available that can suppress, if not kill, the agent; and whether vaccines exist that can be used to immunize a population.

Anthrax is the most common biological agent; it is very toxic, easy to manufacture, and forms a spore that is resistant to environmental degradation. The lethal dosage for anthrax is around 5x10<sup>-4</sup> mg-min/m<sup>3</sup>, compared to about 15 mg-min/m<sup>3</sup> for the most lethal nerve agent VX. Thus, by weight, anthrax is 30,000 as lethal as VX. Because anthrax naturally forms spores, its nighttime aerosol decay rate is low—at most 0.1 percent per minute. The daytime aerosol decay rate is probably on the

order of 5 percent per minute. This low nighttime decay rate is one of the main reasons why anthrax is such a threatening biological agent. It takes 1–6 days before an infected person becomes seriously ill after being exposed to pulmonary anthrax. Once ill, death usually follows within 24 hours. Anthrax is not contagious; hence, the attacker would not have to worry about infecting his own forces if they came in contact with the enemy. If treated in time, antibiotics can be effective for curing anthrax, as with most bacterial infections. Finally, there is a vaccine for anthrax that has been shown to be effective in preventing or significantly reducing the incidence of the disease.

Three other common bacterial agents are plague, tularemia, and Q fever. Plague has roughly the same lethal dosage as anthrax. Untreated pneumonic plague is almost always fatal. However, like most bacteria, plague does not form spores and, hence, it dies rapidly once dispersed into the air. Plague is highly contagious, a factor that may help overcome the limits imposed by its high aerosol decay rate, although the attacker may have difficulty controlling the spread of the disease. Plague can be treated with antibiotics, and a vaccine exists. Unfortunately, the vaccine seems to be effective only against the flea-borne (bubonic) form of the disease and not against the pneumonic form.

Tularemia is a bacterial disease whose lethality is highly strain-dependent, hence the variation in mortality estimates. The effective dosage is about 100 times lower than that of anthrax. On the other hand, it decays rapidly in air.

Q fever also has a very low effective dose and decays slowly in air (matching the decay rate of anthrax). Hence, Q fever would seem to be an ideal biological weapon agent. However, Q fever has a long incubation period of 10 to 21 days (especially at low doses), is seldom fatal even if untreated, and can be easily treated with antibiotics once the symptoms of Q fever appear. Nevertheless, Q fever might be attractive to those adversaries for whom nonlethal biological agents are the weapon of choice.

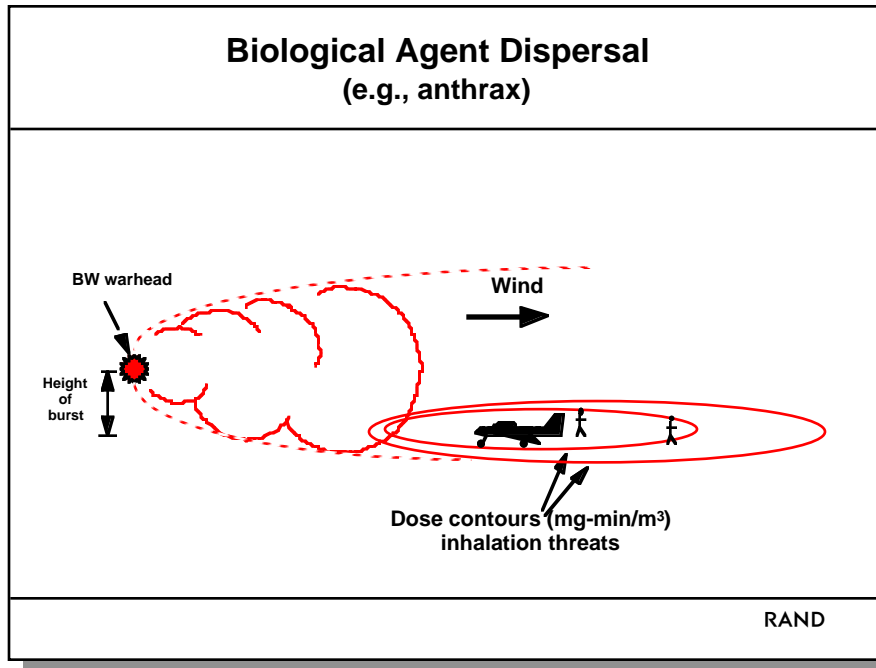
Botulinum toxin is one of the most lethal chemical substances known. Nevertheless, its lethal dosage is still a factor of a hundred higher than that of anthrax, because toxins do not replicate inside the host. In addition, it is a large protein that denatures rapidly in the environment. Its high decay rate limits its ability to be used to attack areas larger than a few square kilometers, because most of the agent decays before the wind carries it far. Botulinum toxin shows its effects within 12–24 hours (the effects of toxins are felt sooner than those of living organisms—again, because replication is not required). Like all toxins, it is not contagious

and cannot be treated with antibiotics, although a vaccine is available for some toxins.

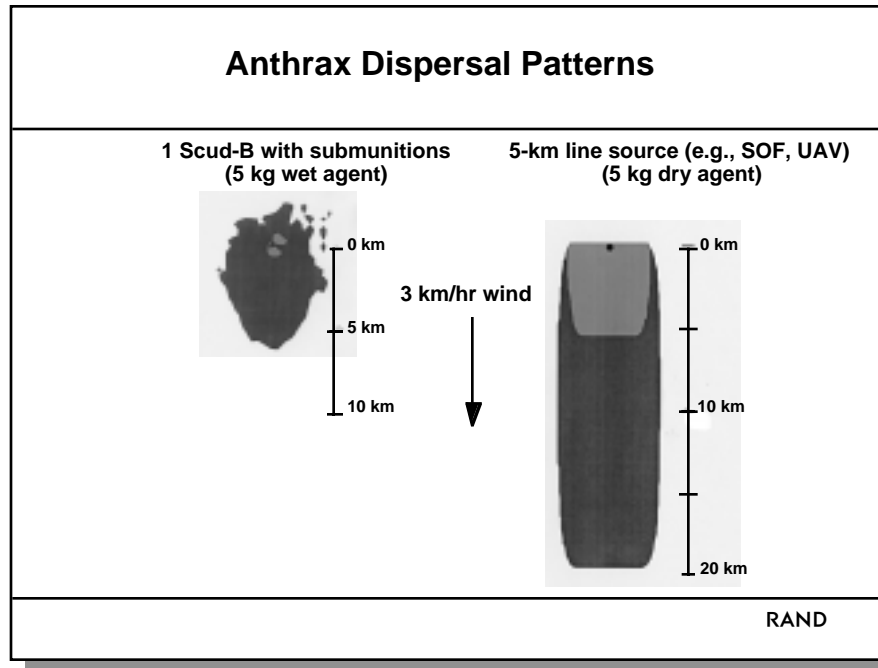
SEB is an incapacitating agent. This toxin is a cause of food poisoning. It has some attractive characteristics from an attacker's perspective. It is a much smaller protein than botulinum toxin and therefore decays in air more slowly. It is not contagious and cannot be treated by antibiotics, and no vaccine currently exists (although one is under development). Since SEB mortality is almost zero, it too may represent an attractive nonlethal BW agent.

Few viral agents make effective biological weapons. Smallpox is a possible exception. The effective dose is about 10 times higher than that of anthrax, and it is fatal in less than half the cases. Unlike most viruses, smallpox decays fairly slowly. On the other hand, it is highly contagious and, like all viruses, cannot be treated by antibiotics. A vaccine does exist for smallpox, although the supply is limited because the effectiveness of past civilian vaccination programs has virtually eliminated the disease worldwide. Hence, smallpox is not believed to be a common threat agent—at least for now. On the other hand, U.S. troops are no longer vaccinated for smallpox. If our adversaries somehow got a sample of the virus and cultured it, smallpox could become a threatening biological agent.

Several other potential agents are not listed in the table because they appear to be less serious near-term threats: Ebola/Marburg, cholera, ricin, brucellosis, and VEE (Venezuelan equine encephalomyelitis). Ebola/Marburg is well known from the popular nonfiction book, *The Hot Zone*. Although it is a lethal viral agent, it commonly does not spread by aerosol. Also, it may be difficult for some countries to obtain samples of the virus, and its high lethality will make it hard to work with. Nevertheless, it may become a future threat. Cholera does not pose much of a threat to U.S. military personnel because it spreads only through contaminated food and water (mediums that are supposed to be monitored closely). Moreover, most infected people do not become seriously ill. (In fact, over 99 percent of infected people do not become ill.) Ricin is a plant toxin, but its toxicity is similar to that of the nerve agent sarin. Hence, it does not pose a more significant threat than that already faced from nerve agents. Finally, brucellosis is an incapacitating bacterial agent, and VEE (Venezuelan equine encephalomyelitis) is an incapacitating virus, neither of which has significant advantages over the agents listed in the table.



The threat posed by the atmospheric dispersal of biological agents is simpler than for chemical agents, because there are no toxic rain or secondary evaporation phases. The main problem is the respiratory threat downwind from the detonation, specifically from biological agent particles in the 1- to 10- $\mu\text{m}$  size range. Any agent that falls to the ground is largely lost, although one must be careful about re-aerosolization of the agent arising from activity on the ground. In addition, there are few percutaneous threats from biological agents. Besides these differences, the effectiveness of biological attacks is determined by many of the same meteorological and delivery factors that affect chemical agents. The above chart illustrates notional contour lines for respiratory exposure downwind from a biological weapon detonated close to the ground.



This chart illustrates the plumes from two different BW attacks using anthrax. The one on the left is a Scud-B attack using 5 kg of anthrax (wet) dispersed in submunitions and the one on the right is a spray source dispersing 5 kg of anthrax (dry) along a 5 km line.

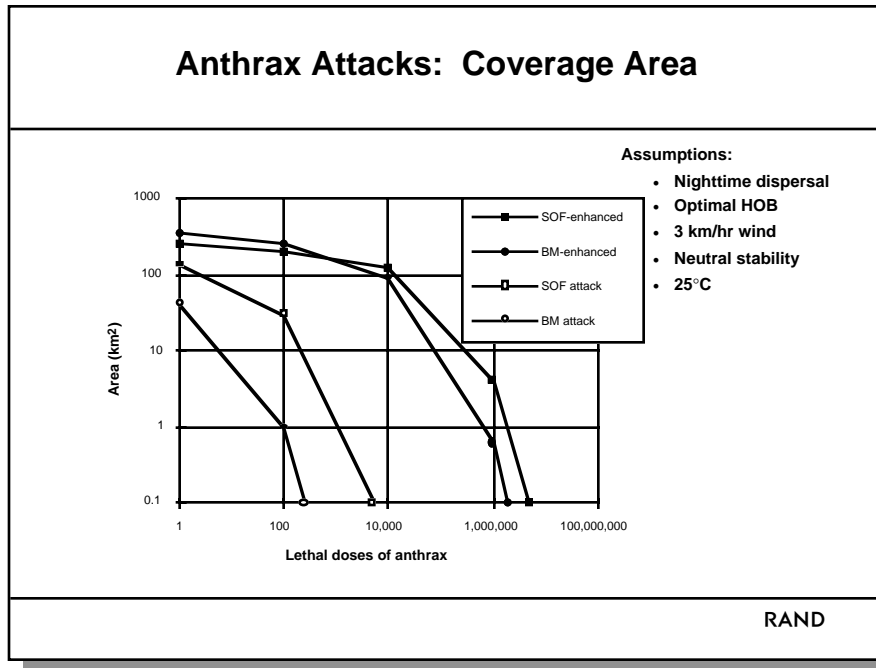
For both the Scud and the spray attacks, we used the VLSTRACK model to calculate the areas covered by 1 (dark gray) and 100 (light gray) anthrax lethal doses. We consider our assumptions to be representative of a current or near-term baseline threat capability.

NOTE: A classified version of the following paragraph is contained in a separate volume.

We assume the Scud attack occurs at midnight and the anthrax decay rate after release is 0.1 percent per minute. The anthrax lethal dosage is 8,000 spores, which leads to a lethal dosage of  $5 \times 10^{-4}$  mg-min/m<sup>3</sup>. The weather conditions are overcast, with neutral stability and a 3 km/hr wind. The footprint of one lethal dose is comparable to an airfield in size. The large scattered area of the submunitions compensates for the missile's inaccuracy. Thus, one arriving Scud can threaten an entire air base and well beyond.

For the nominal spray source attack, e.g., SOF spraying anthrax, we assume that the dry agent is 90 percent pure with a density of 0.1 gm/cm<sup>3</sup>. The agent is released from a sprayer with 60-percent efficiency into the

effective particle size range. The weather condition is the same as the Scud case. The SOF attack covers approximately 30 km<sup>2</sup> with 100 lethal doses or higher and around 130 km<sup>2</sup> with one lethal dose or higher. The lethal area of at least 100 lethal doses is roughly rectangular and extends 5.6 km downwind from the release line. The lethal area of at least one lethal dose is similar in shape and extends 20 km, which shows that special forces will not have to be close to the air base to attack it. It would be difficult for the Air Force Security Police to protect the air base perimeter as far out as 20 km. Unlike a ballistic missile attack, there likely will be no warning unless BW detectors are deployed on base. Without warning, masks will not be used, unless they are worn continuously, and antibiotics will not likely be used until after the first cases of anthrax exposure are recognized. Because of the distribution of incubation times, it may be possible to save many of the exposed people, but fatalities still could be roughly 30 percent. Defeating such attacks, if BW detectors are not available, requires vaccinating people before the attack. Thus, an SOF attack with portable spray canisters would be a very serious threat.



NOTE: A full-size version of this chart can be found in Appendix B.

The above chart provides a convenient pictorial representation of the severity of several nominal biological attacks. Plotting the contaminated area as a function of the number of lethal doses allows us to gauge the impact of various protective measures (e.g., masks, antibiotics, and vaccines)—a topic that is taken up later in this briefing. A single Scud-B missile armed with anthrax submunitions and using an explosive dispensing mechanism to release the anthrax (with a dissemination efficiency around 5 percent) can contaminate approximately 40 km<sup>2</sup> with at least one lethal dose (i.e., with an LD<sub>50</sub> dose—the dose at which 50 percent of the population would die). Since the lethal area of the nuclear attack on Hiroshima was only about 7 km<sup>2</sup>, this shows how potent a BW attack can be. Moreover, around 1 km<sup>2</sup> is covered with at least 100 lethal doses (i.e., 100 times the LD<sub>50</sub>), given the above meteorological conditions. No area is contaminated by more than 10,000 lethal doses. Submunitions are assumed for this notional baseline ballistic missile attack, because a contact-fused unitary warhead carrying a biological agent would bury most of the agent in the impact crater, and even the portion of the agent that was aerosolized would be coated onto dirt particles and quickly settle onto the ground. Submunitions, on the other hand, can achieve reasonable release efficiencies when contact-fused. The alternative is to use an accurate altimeter to fuse the warhead at 50–

100 m altitudes. This is technically more difficult than deploying simple biological submunitions with contact fuses.

One can generate more severe threats by assuming that a dry anthrax agent is used instead of a wet agent (thereby increasing the amount of anthrax for a given kilogram of payload, although one must take into account payload volume constraints), that the submunitions have spray release mechanisms (achieving 60 percent dissemination efficiency), and that the lethality of anthrax can be enhanced a hundredfold by the addition of certain chemicals.<sup>12</sup> Otherwise, the assumptions are the same as in the previous case. Under these circumstances, one Scud-B missile armed with submunitions containing approximately 21 kg of anthrax can cover around 340 km<sup>2</sup> with at least 1 lethal dose, 250 km<sup>2</sup> with at least 100 lethal doses, 90 km<sup>2</sup> with at least 10,000 lethal doses, and approximately 0.6 km<sup>2</sup> with at least 1,000,000 lethal doses. The significance of this vast “overkill” becomes clear when one considers the effectiveness of passive defenses (masks, antibiotics, and vaccines). Masks do not fit perfectly; and at higher exposure levels, enough anthrax will leak in to provide a lethal dose. There is also a fear that at very high doses antibiotics and vaccines might be overwhelmed (this effect has not been demonstrated and, therefore, the required dose is unknown).

The baseline SOF attack illustrated in the chart assumes that 5 kg of dry anthrax is released along a line 5 km long using a spray nozzle (which is easier to implement for aircraft or ground forces than for ballistic missile reentry vehicles). The weather conditions are the same as in the previous two cases. As described in the previous chart, we found that around 130 km<sup>2</sup> is covered with at least 1 lethal dose and about 30 km<sup>2</sup> is covered with at least 100 lethal doses. No area is covered with 10,000 or more lethal doses.

One can generate a notional high-end or enhanced SOF attack by assuming that 50 kg of anthrax is released as a 5 km line source.<sup>13</sup> We also assume that enhanced-lethality anthrax is used. In this attack, 250 km<sup>2</sup> is covered with at least 1 lethal dose, 200 km<sup>2</sup> with at least 100 lethal doses, 120 km<sup>2</sup> with at least 10,000 lethal doses (this area extends 20 km downwind from the release line), and approximately 4 km<sup>2</sup> is covered with at least 1,000,000 lethal doses. In areas covered with at least 10,000

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<sup>12</sup>Enhanced anthrax is assumed to have a lethal dose of only approximately 80 spores, i.e.,  $5 \times 10^{-6}$  mg-min/m<sup>3</sup>. This is only one-hundredth of the typical dose of 8,000 spores.

<sup>13</sup>The generation of such a line source may require the use of a small truck, although multiple point releases from individual SOF agents operating on foot may produce an equivalent result.

lethal doses, there is a real danger that mask leakage could lead to significant fatalities and at least a possibility that antibiotics or vaccines could be overwhelmed. In this situation, at least two passive defensive measures should be used together to ensure personnel protection.

## Do BW Threats Persist?

- **Most agents decay rapidly after release**
- **Some agents may persist for many days:**
  - Anthrax
  - Q Fever
  - Smallpox
- **Reaerosolization may be significant due to aircraft engine exhaust, vehicular traffic, etc.**
  - Needs to be tested for an Air Force base

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Most BW agents decay rapidly after they are released in the atmosphere. Once on the ground, they decay more slowly, although even on the ground most biological agents decay in a day or two. The most common long-lasting agents, i.e., that might persist for a week or more, are anthrax, Q fever, and smallpox. Of these, anthrax appears to be the most serious persistent BW threat.

The key to assessing the persistence of anthrax threats is the effect of low-level exposure. The current LD<sub>5</sub> level (i.e., the dose at which 5 percent of the population would die) for anthrax is estimated to be around 40 spores. This level of respiratory exposure could be achieved by the reaerosolization of anthrax in an area in which tens or hundreds of lethal doses had been deposited, even one week after the attack. Even if one assumes the LD<sub>5</sub> level is much higher, the point remains that high ground concentrations of anthrax imply that modest aerosol concentrations may become possible if the ground is disturbed by vehicular traffic, jet exhaust, etc. There is, however, little fieldwork on the secondary aerosol hazard. The Air Force should conduct tests for an Air Force base.

Unvaccinated personnel would have to wear masks or take prophylactic antibiotics. If one relies on masks, collective protection may also be required. Otherwise, air operations can be disrupted because personnel cannot operate outdoors more than 12 hours without seeking clean areas where the masks can be removed to eat and sleep.

<b>Outline</b>	
<ul style="list-style-type: none"><li>• <b>Introduction</b></li><li>• <b>Potential Threats</b><ul style="list-style-type: none"><li>– <b>Chemical and Biological</b></li><li>➔ – <b>Delivery Options</b></li><li>– <b>When Might Threats Materialize</b></li></ul></li><li>• <b>Possible Solutions</b></li><li>• <b>Conclusions</b></li></ul>	
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## **DELIVERY OPTIONS**

The above discussion introduced several standard delivery options for chemical and biological agents. In this subsection, we provide a quick synopsis of a larger set of potential delivery options.

<b>Possible CBW Delivery Modes</b>	
<p><b><u>Point Sources</u></b></p> <ul style="list-style-type: none"> <li>• <b>Ballistic missile</b> <ul style="list-style-type: none"> <li>– ~500 kg CW (SCUD B)</li> <li>– ~5 kg Anthrax (wet)</li> </ul> </li> <li>• <b>Artillery</b> <ul style="list-style-type: none"> <li>– ~5 kg CW</li> </ul> </li> <li>• <b>Air-delivered bomb (submun.)</b> <ul style="list-style-type: none"> <li>– ~150 kg CW</li> <li>– ~5 kg Anthrax (wet)</li> </ul> </li> <li>• <b>Covert bomb (man portable)</b> <ul style="list-style-type: none"> <li>– ~5 kg Anthrax (dry)</li> </ul> </li> </ul>	<p><b><u>Line Sources</u></b></p> <ul style="list-style-type: none"> <li>• <b>Aircraft spray tank</b> <ul style="list-style-type: none"> <li>– ~1,000 kg CW</li> <li>– ~100 kg Anthrax (dry)</li> </ul> </li> <li>• <b>UAV spray tank</b> <ul style="list-style-type: none"> <li>– ~100-500 kg CW</li> <li>– ~0.5-15 kg Anthrax (dry)</li> </ul> </li> <li>• <b>Covert vehicle spray tank</b> <ul style="list-style-type: none"> <li>– ~150 kg CW</li> <li>– ~50 kg Anthrax (dry)</li> </ul> </li> </ul>
<p><b>Note: All weights are net weights of the agent.</b></p>	
<p>RAND</p>	

In general, delivery modes can be classified by whether they release CBW agents as a point source or as a line source. Point sources give rise to cigar-shaped contaminated areas downwind from the detonation. Line sources give rise to rectangular contaminated areas (for constant wind direction), as illustrated by the anthrax attack simulations shown earlier.

Ballistic missiles with unitary or submunition warheads, artillery shells, aerial bombs, and covert bombs are all examples of point sources. The payloads differ; in some cases, the release mechanism may differ, although, typically, CBW agents are explosively released. Line sources may consist of aircraft spray tanks, UAVs (including cruise missiles), ships, and trucks. Here, the dispersal mechanism is a spray nozzle that typically achieves much higher dispersal efficiencies for BW agents. Again, the payload varies for different line sources, giving rise to smaller or larger rectangular contaminated areas. Typically, the largest contaminated areas are generated by aircraft spray tanks because of the large payload and high dispersal efficiency.

## Assessment of Delivery Options (1)

- **Ballistic missiles attractive for CBWs**
    - Survival and assured penetration
    - Accuracy may be a problem for some chemical weapons
    - Fuzing may also be a problem (need accurate altimeter)
    - Submunitions preferred for BW
  - **Aircraft can be used for CBW delivery**
    - High performance aircraft readily available to most countries
    - Good range-payload
- BUT...**
- Pre-launch survivability is low
  - Low penetration through U.S. air defenses
  - High cost (esp. pilots) relative to missiles

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The major advantages of ballistic missile delivery are the survivability of the delivery vehicle (assuming it is mobile) and the current lack of adequate defenses. Ballistic missile payloads, although modest, are adequate for carrying biological and chemical weapons. Their limited accuracy suggests that conventional warheads are less useful. Typical targets will be large, fixed-area targets—cities, airfields, ports, etc. Thus, ballistic missiles make excellent weapons of terror. It should come as no surprise that ballistic missiles are proliferating in regions of the world where the spread of WMDs is of concern.

Submunitions help compensate for ballistic missile inaccuracy, complicate defenses, and may be essential for effective BW delivery. Biological agents must be dispersed close to, or on, the ground to be effective (since they are nonvolatile).<sup>14</sup> Optimal burst heights are around 50–200 m, depending on meteorological conditions. BW warheads must either be contact-fused or be fused to detonate close to the ground. The latter is technically challenging, so first-generation BW weapons frequently use contact fuses. This presents a problem for unitary ballistic missile warheads, since contact-fusing buries most of the biological agent in the impact crater or causes the BW agent to become coated onto dirt particles that quickly

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<sup>14</sup>If submunitions are used, there is less need to predict wind direction, since the submunition pattern can be made large enough to cover some targets (e.g., an airfield).

settle onto the ground. Submunitions avoid this problem and achieve reasonable agent release efficiencies.

A disadvantage of ballistic missile delivery is that it provides tactical warning, although the defender does not know the warhead type until detonation. If U.S. forces are in an area where CBW threats are suspected, tactical warning alone may cause U.S. troops to don their protective gear.

Aircraft can be used as delivery vehicles for NBC weapons. Modern fighter-bombers are widely available and have good range-payload characteristics for WMD delivery. Their principal disadvantages, at least for adversaries facing the United States, are relatively low survivability on the ground, inability to penetrate U.S. theater air defenses, and high cost relative to UAVs (especially if pilot training is taken into account).

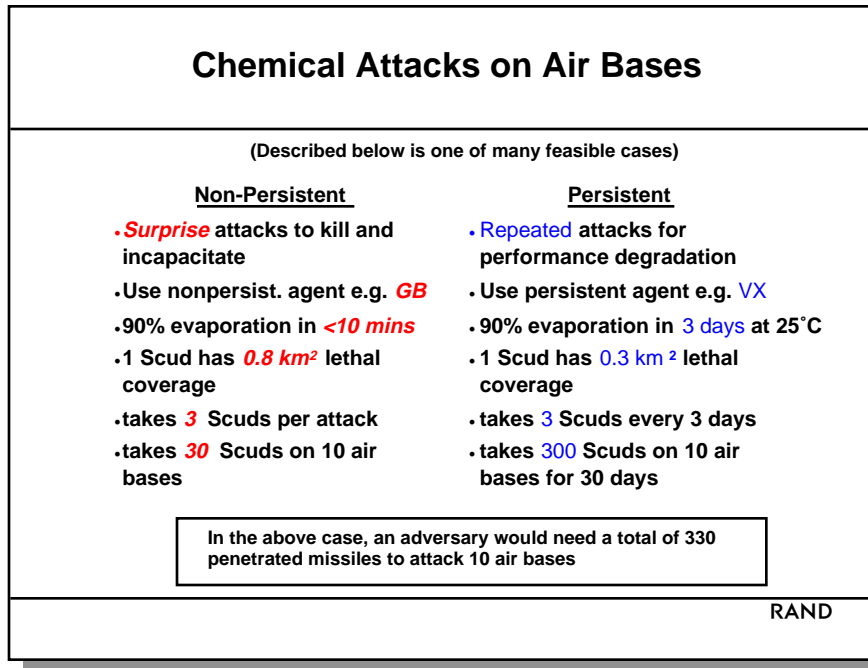
## Assessment of Delivery Options (2)

- **UAVs attractive for BW, possibly CW**
    - Small, easy to develop or buy
    - Good prelaunch survivability
    - Adequate range and payload for BW, possibly CW
    - May be able to penetrate air defenses (e.g., LO, slow, low altitude)
    - Accurate if GPS aided
  - **Covert options (covert emplacement, ships, trucks, etc.)**
    - SOF attractive for BW
      - Little tactical warning
      - Long range
- But**
- Difficult to attack multiple targets simultaneously
  - Risk of discovery due to long lead times
  - C<sup>3</sup> problems

RAND

UAVs (including cruise missiles) are more attractive for BW than for CW delivery because of payload constraints. UAVs are small, easy and cheap to acquire, and perhaps could be manufactured indigenously—although few UAVs have been observed to date in the arsenals of countries that concern the United States. The prelaunch survival of UAVs is relatively good because they are mobile and can easily be hidden. The wide range of potential launch platforms certainly complicates counterforce attacks. The principal drawback with UAVs is their limited range (several hundred kilometers, depending on the UAV's size). Larger UAV payloads are suitable for CW delivery, while payloads as small as several kilograms would be adequate for many BW attacks, especially if spray dissemination techniques were used. Some of the greatest potential advantages of UAVs are low cost, ease of acquisition, and ability to penetrate air defenses. If UAVs can be programmed to fly at low altitudes (which requires good information on the terrain they will fly over, as well as accurate radar altimeters), they may not be detected until they are quite close to their targets. Flying at low altitude will also make them harder for airborne platforms to detect because the UAVs will be hidden in ground clutter. Some UAVs also fly very slowly (<50 knots), which allows them to avoid detection by airborne radars because such speeds are below the doppler cutoff. Finally, UAVs using the Global Positioning System (GPS) will be quite accurate (their navigation accuracy will probably be around 20 m CEP; however, the overall system CEP must take into account targeting errors).

Covert delivery by special forces has a number of advantages: a wide range of platforms (e.g., ships, trucks, foot), efficient dissemination with spray release, stealth (i.e., limited tactical warning), and few range constraints. In fact, SOF delivery may be one of the few ways to attack the U.S. homeland with WMDs. Nuclear SOF attacks might be risky for an adversary, since it must part with a precious asset (one of its few nuclear weapons) and must trust a team of special agents to remain loyal, to deliver the weapon without being discovered, to detonate it if commanded to do so, and to return it if the attack is called off. For CBW attacks, the larger potential inventory of weapons reduces these concerns with SOF delivery. Nevertheless, it may still be difficult to coordinate SOF attacks against many targets in a theater simultaneously (attack conditions may be ripe for some targets but not others); it may be difficult to mount and control attacks on targets deep in a country's interior; and follow-up attacks may be difficult.



This chart illustrates notional CW attacks against airfields using ballistic missiles. The objective for the first day of the attack is assumed to be to cover the base with lethal respiratory doses of CW agent in an attempt to kill as many people as possible since they may not be in protective gear (especially if tactical warning is short or is denied). Since sarin from each Scud will cover about 0.8 km<sup>2</sup>, three Scuds would be needed to cover a significant fraction of an air base. Missile accuracy will affect the number somewhat, although current Scud accuracy is probably good enough for effective air base attack. In a Korean contingency, at least about 10 air bases will be used by U.S. aircraft. Then, it would require 30 Scuds to mount a surprise attack on all 10 airbases.

We assume that the base personnel are in protective gear on subsequent days. The objective of the opponent is to slow down the U.S. operational tempo by keeping the U.S. personnel in full MOPP gear. Since each Scud carries enough VX agent to cover about 0.3 km<sup>2</sup> and the VX continues to produce a dangerous amount of secondary evaporation for three days (under the conditions described earlier), three Scuds would be required every three days for each air base. Thus, it would take 300 Scuds to keep 10 air bases under siege for 30 days. The total number of Scuds needed for the initial and subsequent attacks would be about 330.

## Airfield Attack Strategy With BW

- **Exploit lack of U.S. real-time detection capability to defeat masks**
  - Cruise missiles and SOF are preferred options
  - Ballistic missiles are less effective due to tactical warning
  - Encapsulate BW agents
- **Attack requirements (nominal attack):**
  - 1–3 UAVs per airbase
  - One 1–10 man SOF team
- **Attempt to saturate masks, antibiotics, vaccines with very high lethal dose attacks**
- **Exploit weaknesses in U.S. vaccine program**
  - Use Smallpox, new agents?

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The attack strategy for BW is a bit different than for CW. For BW attacks, little is gained by forcing the opponent into protective gear, since only a mask is required, rather than the full protective suit for CW. Hence, repeated attacks on the base have less impact on air base operational tempo once the ground crew is wearing masks, unless, of course, there are no collective protection facilities. If there are none, the ground crew cannot remove their masks to eat, sleep, and recuperate. An adversary might try to deny tactical warning in an attempt to kill or incapacitate as many air and ground crews as possible in the first attack. This is not difficult, since the United States currently lacks real-time BW warning and identification capabilities. UAVs and SOF teams probably provide the best means for avoiding detection. Encapsulating BW agents may be another way to avoid detection. As a rough estimate, one to three UAVs or one 1- to 10-man SOF team should be sufficient to attack an air base in this manner.

If tactical warning cannot be denied, a second approach would be to attack the air base with such high concentrations of the BW agent that the mask and medical treatment might be overwhelmed (for some segment of the base population). Recall the overkill available with the anthrax attack options discussed earlier. Or the adversary might try to exploit known weaknesses in the U.S. vaccine program by using agents for which no vaccine exist or no vaccination is routinely given.

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## **WHEN MIGHT THREATS MATERIALIZE?**

Having discussed theoretical CBW threats, we next turn to a brief overview of the current status of CBW proliferation.

## CBW Production Is Difficult to Monitor

- **CW and BW production involve dual-use technology**
- **CW production of militarily significant quantities is easier to detect than BW**
  - Activities occur on large scale
  - However, exact CW inventories are difficult to estimate
- **BW production is hard to detect**
  - Militarily significant quantities can be made in labs or research environments
    - **Can be produced in a few weeks**
    - **Look for circumstantial evidence of BW production (security, storage, special equipment?)**
  - Agent identification is extremely difficult
  - Inventories are very difficult to estimate

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Before examining the intelligence data, it is important to understand that CBW production is easy to conceal, especially when commercial production is used as a cover. Hence, although U.S. intelligence agencies make every effort to construct an accurate picture of the extent and character of CBW proliferation, proliferation activities are difficult to monitor. Intelligence estimates can be misused to give a false sense of security if a certain activity is not observed or to give rise to exaggerated threats if some activities are uncovered. As a general rule, CW production is easier to detect than BW production, because larger industrial facilities are required to produce the CW stockpiles needed for military applications. But estimating the size of CW stockpiles and determining the identity of CW agents are still difficult.

BW agent production is more difficult to monitor because smaller quantities are used in military applications. Biological research labs or pharmaceutical labs could be converted to produce militarily significant quantities of anthrax, for example. Moreover, even if dedicated BW facilities did not exist, other biological facilities could be converted for the purpose on short notice, giving rise to small quantities of BW agents within several weeks or months. A BW facility could, however, be revealed by special security and other arrangements at the site (although Iraq's BW facilities were not detected before the Gulf War). Stockpile size is also difficult to estimate, as is the identity of the agents being produced. This has important implications for passive defenses, because the

effectiveness of antibiotics and vaccines depends on knowledge of the agent, even if not the exact strain, to which one may be exposed. This poses daunting challenges for BW intelligence collection.

Proliferation of CW					
	Mustard	VX	Sarin	Soman	Tabun
Middle East					
Asia					
C = confirmed, L = likely, P = possible, S = suspect					
RAND					

NOTE: A classified version of this chart and its annotation is contained in a separate volume.

About a dozen countries are believed to have either confirmed or suspected offensive CW programs,<sup>15</sup> with more on an intelligence community watch list.

<sup>15</sup>The Office of Technology Assessment lists the following countries as possessing or pursuing chemical weapons: Iran, Iraq, Israel, N. Korea, China, Libya, Syria, Taiwan, Egypt, Myanmar, and Vietnam. See *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559, Washington D.C.: U.S. Government Printing Office, August 1993, p. 15.

Proliferation of BW	
Agents	Countries
Anthrax Bot Tox Q-fever • • •	
RAND	

NOTE: A classified version of this chart and its annotation is contained in a separate volume.

As with the assessment of foreign CW programs, there is considerable uncertainty on the status of BW programs. The following countries are believed to possess or pursue biological weapons: Iran, Iraq, Israel, N. Korea, China, Libya, Syria, and Taiwan.<sup>16</sup>

<sup>16</sup>Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559, Washington D.C.: U.S. Government Printing Office, August 1993, p. 15.

<b>Future BW Threats</b>
<p><b>Future threat has large growth potential</b></p> <ul style="list-style-type: none"><li>• Enhanced anthrax, smallpox, Ebola, and others</li><li>• UAV delivery</li><li>• Additional threat countries</li></ul>
RAND

NOTE: A classified version of the annotation below is contained in a separate volume.

The future BW threat has a large growth potential. Countries can develop enhanced lethality anthrax, smallpox, Ebola, or other nontraditional agents. Cruise missile or UAV delivery may become widespread. Finally, more countries (and possibly also terrorist organizations), will probably acquire BWs.

## Ballistic Missile Delivery

	Range (km)	Payload (kg)	Inventory
<b>North Korea</b>			
Scud-B	280	550	100+
Scud-C	600	280	100s
No Dong-1	1,000+	560	0
<b>Iran</b>			
Scud-B	280	550	200+
Scud-C	600	280	100+
No Dong-1	1,000+	560	0

Source: Center for Nonproliferation Studies, Monterey Institute of International Studies, 1995; and Office of the Secretary of Defense, *Proliferation: Threat and Response*, April 1996, pp. 8 and 16. The authors have adjusted payloads for carrying chemical agents.

RAND

NOTE: A classified version of this table and its annotation is contained in a separate volume.

Potential adversaries of the United States have large numbers of ballistic missiles. As discussed earlier, these missiles can be effective for delivering CBW to high-priority military targets to theater airfields, ports, command and control centers, and logistics nodes.

## When Might Threats Materialize?

- **CBW inventories**
  - Difficult to determine exact CBW stockpiles
  - Chemical stockpiles of the most dangerous persistent agents are growing
  - Biological stockpiles are growing
- **Delivery vehicles**
  - Ballistic missile attacks are a serious option
    - qualitative characteristics are barely adequate (CEP, fuzing, payload, range, etc.)
    - inventories are adequate for unprotected bases
  - Cruise missiles likely to be a growing threat
  - Covert delivery (e.g., SOF) should be taken seriously

**CBW will pose a growing threat to airbases over the next 10 years**

RAND

By comparing intelligence estimates of CBW programs and delivery vehicle inventories with theoretical attack requirements, one can determine whether CBW threats pose a present danger. Keep in mind that CBW inventories are difficult to determine both in terms of agent type and amount. This is important because whether an opponent has VX or mustard gas makes a big difference. Despite the lack of precise intelligence, it is safe to say that inventories of persistent CW (specifically VX) and BW agents appear to be growing. Hence, whether CBW threats are a current problem or will become one within a decade, the United States should begin to take these threats seriously in its defense planning.

In terms of delivery vehicles, ballistic missile proliferation is the greatest near-term threat. Some countries (e.g., North Korea) are just beginning to achieve inventories that are sufficient to pose a serious threat to allied airfields in theater. Moreover, the qualitative characteristics of these ballistic missiles (e.g., range, payload, accuracy, and fusing) are reaching the point where CBW delivery via ballistic missiles is a viable option. Cruise missile proliferation is likely to become a serious problem within a decade, although little concrete evidence exists to quantify this threat today. Finally, delivery by special forces should be taken seriously by the Air Force, since it is a viable way to attack airfields, especially with BW agents. In short, biological and chemical weapons will soon pose a credible threat to overseas airfields, if they do not already, and the threat appears to be growing.