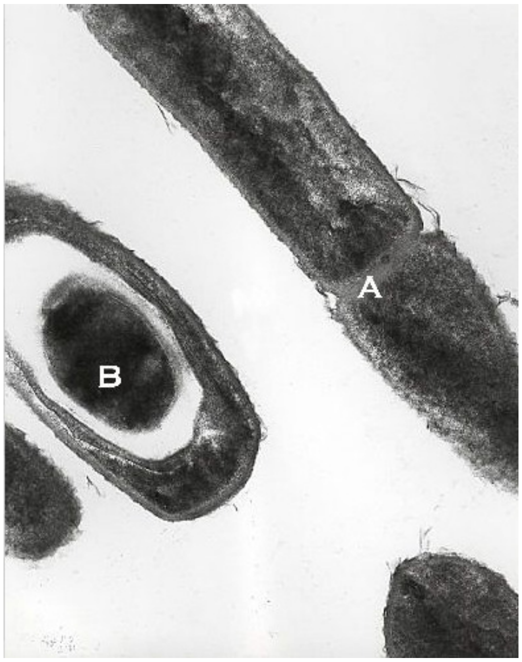
ANTHRAX

AristaTek was recently approached by a state/local organization that was planning a response to a mock terrorist incident where anthrax spores were released upwind of large outdoor sporting event. The specific question was whether there are any dispersion models available that could predict the dispersion of released anthrax, and what should be the level of concern. The short answer was "no", at least not in the sense of predicting downwind dispersion of a toxic chemical such as chlorine and establishing a level of concern. Information is available, but the dispersion of anthrax spores and establishing a level of concern is much more complex than a simple toxic chemical dispersion. We will look at how anthrax spores infect people, how many are required to infect, lethality, dispersion of spores in the air, and cleanup of contaminated locations.

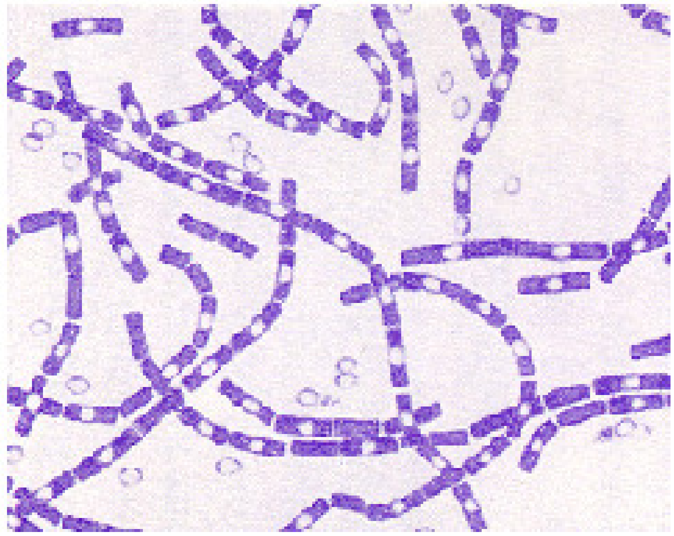
The Anthrax Spore

The anthrax spore is a tiny particle about 0.9 to 1.5 micrometer in diameter produced by the bacterium, *Bacillus anthracis.* The bacterium itself is rod-shaped, approximately 1.0 to 1.2 micrometers in diameter and 3 to 8 micrometers long. To get an idea of size, a human red blood cell is typically 6 to 8 micrometers in diameter. The rod-shaped bacteria (the vegetative form) require an animal (including humans) to reproduce and grow; if the animal dies, the bacteria in hemorrhages and other body fluids leaving the dead animal form spores when the fluids dry out. Only one spore is formed per bacterium. The spores resist drying, cold, heat and can remain viable for many years in the soil, water, animal hides, and animal products. Spores 70 years old can still infect. Sunlight can kill spores. If a spore is inhaled by another animal (including people) or is ingested or gets in a skin cut, there is potential for the spore to 'germinate" forming the vegetative form of the bacterium. The bacteria grow, reproduce within the animal, and produce several protein toxins. The body is overwhelmed by the protein toxins and dies. Theoretically, only one spore could potentially kill an animal, but the body also has a number of defenses. It is only if the body is overwhelmed with many spores or the body immune system is compromised, will the animal (or person) come down with the disease. The spores and bacteria also incorporate strategies to overcome body defenses. Typically, several hundred thousand spores are required to kill a healthy animal if ingested, a few thousand or tens of thousands of spores if inhaled, and less than 10 spores if injected directly into the body cavity.

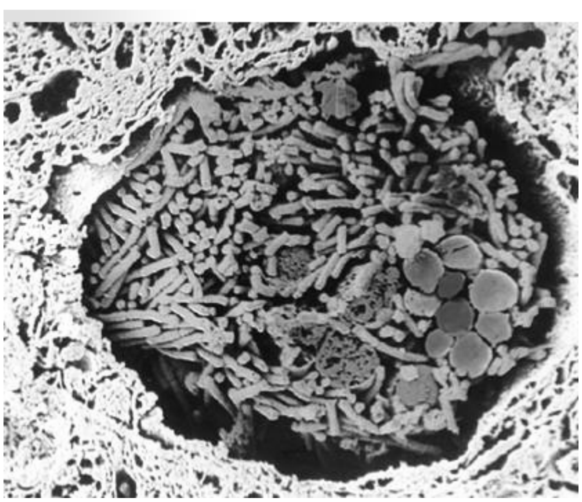
The writer of this newsletter (John Nordin), while a student at the University of Minnesota, took a microbiology course which included the culture and diagnostic identification of *Bacillus anthracis,* including the preparation of Gram stains. The bacteria could be easily cultured in the laboratory. Everything was done under strict supervision, which included controls to insure that no material could be removed from the laboratory, and no student came in direct contact with the bacteria.



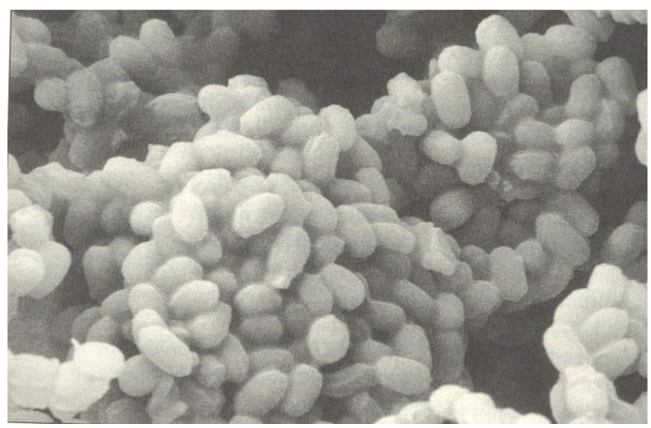
A= *Bacillus anthracis;* B = spore formed inside a "killed" bacterium". Photo from http://www.anthraxinvestigation.com/coatings.html.



Top, Gram stain of *Bacillus anthracis* forming spores. The bacteria (laid end-to-end forming a chain) are stained violet, but the spores are unstained. The square ends separating the bacteria are diagnostic, and can be used to distinguish this *Bacillus* from several other species. The procedure for a Gram stain is at http://www.microbiol.org/white.papers/WP.Gram.htm. This photo from http://www.textbookofbacteriology.net/Anthrax.html.



Electron microscope photo of *Bacillus anthracis* cluster in a capillary of a lung. Photo from http://encarta.msn.com/media_461522413_761551611_-1_1/anthrax_bacteria.html.. Citation:
A.B. Dowsett/Science Source/Photo Researchers, Inc



Pure Anthrax spores, photo from U.S. Army Medical Research Center of Infectious Diseases, photo used in http://www.anthraxinvestigation.com/coatings.html. For a colorized image of a single anthrax spore showing the spore's tough outer coat and internal structure, visit http://www.med.umich.edu/opm/newspage/2003/anthraxspores.htm.

Weaponization of Anthrax Spores

Details on how to do this are not available to the writer, but generally the steps are (1) mass culture of the bacteria in suitable media, (2) changing growth conditions to encourage spore formation (dehydration, exposure to air), (3) repeated washing and centrifugation of the residual bacterial material to separate spores from other extraneous material, and (4) coating the purified spores with a specialized coating to reduce electrostatic charge which would otherwise result in spore clumping. The final product is a fine powder maybe 0.9 to 1.5 micrometers in diameter which is easily dispersed in the air. Theoretically, one gram of purified anthrax spore material can contain as many as one trillion (10^{12}) individual spores. An estimate of the number of spores contained in one gram of anthrax spore material sent in the two 2001 letters to United States Senate leaders was roughly one hundred billion (10^{11}) spores.

United Nations weapon inspectors in Iraq prior to the U.S. invasion of Iraq (see http://www.anthraxinvestigation.com/coatings.html and ABCNEWS website dated 1 November 2001) reported that bentonite was used to coat anthrax spores in the Iraq weaponization program. The same website also discusses a possible use of silicon nanoparticles (5 to 70 nanometers in diameter) as a coating for anthrax spores [recall that the spore diameter itself is maybe 900 to 1500 nanometers].

Researchers at Clemson University [see Nanotechnology / Bio & Medicine, 3 October 2006, summary at http://www.physorg.com/news79106478.html.] reported on the development of sugar-coated carbon nanotubes to spray onto weaponized anthrax spores to stop their infection capability. Nanotubes of carbon are about 1/1000 the thickness of a human hair, and if sprayed (as a water-based foam or aerosol) into a room contaminated with anthrax spores, binds onto the spore surface causing them to clump and making the spores too large to be inhaled.

Fortunately, nature does not weaponize spores which enter the environment naturally. Most human cases result from either consuming contaminated meat or from spores entering a skin cut while working with contaminated animal hides or from soil contaminated by a deceased animal. Natural inhalation anthrax is very rare, and again involve people handling contaminated animal hides or hair. Also, soil contains a complex mixture of microorganisms and fungi, and over time, could scavenge residual spores.

Direct person-to-person spread of anthrax is also unknown. However if the person (or animal) dies, spores may form in any blood or fluids which leak from the body and are exposed to air. Therefore precaution must be taken in handling or disposal of the body to prevent infection.

In 1979, aerosolized anthrax spores were accidently released from a Soviet Union military facility affecting 94 people and killing 64 people (another source said 79 cases and 68 deaths).

The largest recent human outbreak of anthrax occurred in Zimbabwee during its 1978-1980 civil war, resulting in about 10,000 human cases and 151 documented deaths (see http://www.siumed.edu/medicine/infectious-diseases/current_issues/anthrax.htm and Kobuch et al, Salisbury Medical Bulletin, Proceedings of the International Workshop on Anthrax, 1990, vol 68(supplement)).

Weaponized stocks of anthrax spores in the United States were destroyed in 1971-1972 after President Nixon ordered dismantling of the US biowarfare programs in 1969 including the destruction of all existing stockpiles. Research continues on the development of vaccines and on protection against bioweapon attacks.

Anthrax Threat Letters

Experimental Test:

The Canadian National Defense sponsored a series of experimental tests to determine the risk assessment to personnel opening threat letters containing anthrax spores, following an incident where a threat letter claiming to contain anthrax was sent to the Office of the Minister of Citizenship and Immigration on 30 January 2001, and other threat letters sent to government offices in Toronto. The results of the unclassified tests were made available to anyone interested [citation: B. Kourmikakis, et al. "Risk Assessment of Anthrax Threat Letters", Defence Research Establishment Suffield, Technical Report DRES TR-2001-048, September 2001, report available at http://anthraxinvestigation.com/canadiananthraxstudysep01.pdf.].

In these tests, *Bacillus globigii* spores (BG) were obtained from the U.S. Department of Defense for the test setup. *Bacillus globigii* spores are routinely used as a safe alternative for dispersion tests instead of using the dangerous *Bacillus anthracis* spores. One gram or 0.1 gram samples of BG spores (density 10^{11} spores per gram) were placed inside standard letter envelopes along with standard 8.5x11 inch copy paper. A test consisted of a subject seated at a table opening a letter in the 18 x 10 x 10 ft room space; the subject was fitted with a respirator with a special collection filter to collect the spores which normally would have been inhaled. The subject removed the copy paper from the letter and placed it on the table, stood up, and remained standing for ten minutes. The subject wore protective clothing which was later swabbed to collect spores. In addition, various slit samplers were placed throughout the room to collect spores. The samples collected were plated onto nutrient agar plates and incubated overnight at 37^{o}C (body temperature). Six tests were performed.

The tests showed that the spores quickly dispersed throughout the room. The concentration of spores in the room reached its peak shortly after opening the letter and then declined slowly throughout the ten-minute sampling period. About 99% of the particles collected by respirator collection filter were in the 2.5 to 10 micrometer range, indicating that the dispersion consisted of agglomerations of individual spores. The assumption was made that the number of colonies counted on the nutrient agar plates is equivalent to the number of viable particulates collected and dispersed on the plates. During a ten-minute test, the subject opening a letter containing 0.1 gram of spores, room air recirculation rate 1050 cfm, the respirator collection filter worn by the subject collected 1.2 million viable particulates. For the 1-gram spore test, the collection filter collected 6.7 million viable particulates. The Canadian report cited a lethal dose sufficient to kill 50% of the persons exposed (LD_{50}) as between 2,500 and 55,000 inhaled anthrax spores. Each viable particulate particle could contain more than one viable spore. A little arithmetic shows that the subject could have inhaled many lethal dose equivalents of anthrax spores when opening a spore-laced letter.

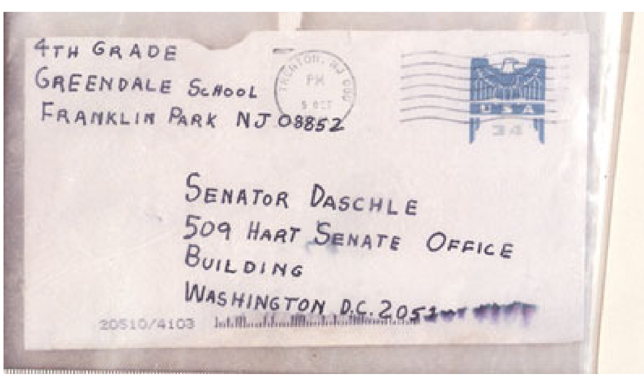
Further Canadian tests showed that not only is the person opening the letter at risk, but so are other people in the room. If the letter is not completely sealed, it can pose a threat to individuals in the mail handling system. The contamination could be spread via the person's clothing and by anything the person touches.

The experimental tests showed that the dissemination of anthrax spores from an envelope presents a far more serious threat than had been previously assumed. Consequently anthrax threat letters or letters containing fine powders are taken very seriously.

2001 Anthrax-contaminated Mail

The U.S. Center for Disease Control issued a report on the U.S. anthrax mailing incidents which occurred following the 2001 World Trade Center and Pentagon attack on September 11. Their report is available at http://www.cdc.gov/ncidod/eid/vol8no10/02-0353.htm.

From October 4 through November 20, 2001, 22 cases of anthrax were identified in the United States, 11 of which were inhalational and 11 were cutaneous; 5 of the inhalational cases were fatal. Twenty of the 22 cases were either mail handlers or were exposed to worksites where contaminated mail was processes or received. The other two cases (a retiree at home and a hospital supply worker) required further investigation to establish a link.



The return address is fictitious. All four letters were pictured on an FBI and US Postal Sevice reward poster.

Bacillus anthracis spores were isolated from white powder or brownish granules contained in four envelopes. The four envelopes were mailed in or around Trenton, NJ, postmarked September 18 or October 9, 2001, and sent to NBC news anchor Tom Brokaw, the editor of the New York Post, Senator Tom Daschle, and Senator Patrick Leahy, and contained such threatening messages as "09-11-01… You cannot stop us. We have this anthrax. You die now. Are you afraid?" None of the addressed people opened the letters.

Handlers of September 18 mailings addressed to news personnel came down with cutaneous anthrax; the New York Post letter contained what was described as a coarse brown granular material. The October 9 Senator mailings contained a fine whitish powder which was responsible for the more deadly inhalation anthrax. The Daschle letter was opened by an aid; the Leahy letter was not opened, but one postal employee who apparently handled the Leahy letter died.

One of the inhalation deaths with no apparent link to the mailings involved a 94-year-old female retiree in Oxford, Connecticut, who became ill on 14 November 2001. Environmental sampling ruled out her home or nearby areas as a source of the anthrax. Further investigation showed that she would have received mail from a processing center in Wallingford, Connecticut, and this processing center received mail from the contaminated postal facility in Hamilton, New Jersey. One of the envelopes recovered from another person four miles away from resident of the 94-year-old who died was found to test positive for anthrax spores; the envelope had been run through the Hamilton processing center sorter 15 seconds after the implicated envelopes sent to U.S. Senators. Considering the indirect path that the mail took, the suggestion has been made that the 94-year-old probably inhaled only a few spores, and that was enough to result in her death.

FBI investigation, which involved sampling about 600 mailboxes in the Trenton area, discovered only one mailbox containing anthrax spores, located at 10 Nassau Street, Princeton, New Jersey, near the University campus.

Further investigation showed that both the brown granular material sent to news media people and the fine powder sent to the Senators were of the Ames strain anthrax, and that the anthrax material was produced within two years of the 2001 mailings. The Ames strain was first researched at the Army Medical Research Institute of Infectious Diseases in Fort Detrick, Maryland, and then distributed to at least 15 research laboratories within the United States and six locations overseas.

Eventually, the FBI investigators in 2008 singled out a 62-year old researcher who worked at the biodefense lab at Fort Detrick as the person responsible for the attack. The researcher was involved in producing a second generation anthrax vaccine and was working with that particular strain. The researcher committed suicide when the FBI was reported to lay charges on him. The evidence against the researcher was reported to be circumstantial, and critics of the investigation claimed that the researcher apparently had no motive for an attack nor possessed skills for weaponization. There were also other possible suspects considered “persons of interest”. There is a lot of discussion on the Internet on the investigation including motives of other possible suspects and reports of missing anthrax from Fort Detrick, but this writer has not seen an official report. One of the 9-11 hijackers who died in the Pennsylvania crash had earlier been treated at Holy Cross hospital in Fort Lauderdale, Florida, for cutaneous anthrax.

The decontamination of two postal facilities cost $195 million. The decontamination of government buildings in Washington D.C. cost $41.7 million. Chlorine dioxide gas was used in the decontamination. Authorities interviewed over 9000 people, conducted 67 searches, and issued over 6000 subpoenas. The FBI estimated that the total damage exceeded one billion dollars.

Level of Concern

When a gas dispersion model is used to predict atmospheric downwind concentrations resulting from a chemical spill, the chemical concentrations are usually expressed in units of part per million (ppm) or milligrams per cubic meter (mg/m^3). The exposure duration is also important in estimating a dose. The person may inhale the chemical or it may be absorbed through the skin. Ingestion can also be a route of exposure. Lists of Levels of concern expressed as concentrations in the air linked to various exposure times have been published for many toxic chemicals.

When dealing with bioweapons such as anthrax spores, things become much more complex. We are interested in the number of anthrax spores required to result in death, expressed as LD_{50} (lethal dose required to kill 50% of test animals exposed to anthrax spores). But the number of spores required to kill depends on many factors:

1. There are at least an estimated 90 strains of anthrax identified and studied, with varying degrees of lethality. There may have been more developed in the Soviet Union.
2. The lethality depends on the route of exposure, with direct injection into the abdominal cavity being the most lethal and ingestion of spores the least lethal.
3. Most test data on lethality has been obtained using animals, and there are unknowns in extrapolating the information to humans. Limited information seems to suggest major differences in lethality comparing rats, mice, and monkeys as test subjects, or comparing cattle and human cases. Carnivores appear to be immune to ingesting anthrax or its spores.
4. Lethality depends greatly on the health of a person's immune system.

Some published numbers include:

1. Median LD_{50} = 61,800 colony forming units (viable anthrax spores, Ames strain), results of a test where 14 Cynomolgus monkeys were exposed to spores by inhalation; 95% confidence limit 34,000 to 110,000 colony forming units, see http://www.nature.com/labinvest/journal/v83/n8/abs/3780709a.html. The Ames strain is not as deadly as some other strains.
2. The U.S. military estimates between 8000 and 50000 spores inhaled on the battlefield results in inhalation anthrax, if unvaccinated (see http://www.gulflink.osd.mil/bw_ii/bw_tabc.htm.)
3. T.V. Inglesby et al, "Anthrax as a Biological Weapon", JAMA, vol 281, 1999, pages 1735-1345, based on primate data the estimated LD_{50} is between 2500 to 55000 inhaled anthrax spores. This number is also cited in several Internet sources.
4. A University of Vermont report (published in 2003) [see http://www.fahc.org/Healthcare_Providers/Healthcare_Providers_Contribution/Bioterrorism_Curriculum/Email_4_April_14.pdf.] reviewing inhalation tests on monkeys cites a

LD_{50} value of 4000 anthrax spores, with some monkeys killed by inhaling only a few spores. As little as 1 to 3 viable spores if inhaled can kill.

5. Another Internet source sponsored by the University of Alabama [http://www.bioterrorism-uab.ahrq.gov/CategoryA/Anthrax/summary.asp.] estimates a value of LD_{50} between 10,000 and 20,000 spores for inhalation anthrax for humans with intact immune systems, but LD_{50} could be 10 to 50 spores if injected into cuts or abrasions.

Disease Description

Inhalation Anthrax

The University of Alabama website [http://www.bioterrorism-uab.ahrq.gov/CategoryA/Anthrax/summary.asp.] presents the following description of what happens when spore-bearing particles deposit into the alveolar spaces of the lungs:

Macrophages ingest the spores, some of which undergo lysis and destruction. Surviving spores are transported by macrophages to mediastinal lymph nodes, germinate into vegetative cells en route and intensively multiply once in the lymph nodes. Once multiplication has begun, disease follows rapidly. The infection rapidly progresses through the following pathogenetic stages:

- Accumulation of vegetative cells in the lymphatic system and lymphoid tissue-containing organs (spleen, liver, and lymph nodes). This stage is characterized by low bacteremia and low toxemia
- Increasing bacteremia, toxemia, and rapidly accumulating organisms of bacilli in the lymphatic system and organs
- Rapidly accumulating organisms of anthrax toxins in blood and lymph
- Increasing massive mediastinal edema, hemorrhagic thoracic lymphadenitis, hemorrhagic mediastinitis, and sometimes hemorrhagic meningitis
- Increasing respiratory dysfunction and increased vascular permeability induced by anthrax toxins
- Mediastinitis
- Sepsis
- Septic shock and death

Inhalation anthrax is almost 100% fatal if untreated and symptoms appear.

Cutaneous anthrax

The University of Alabama website also provides a description of cutaneous anthrax, following the deposition of spores in cuts and abrasions:

After the spores germinate in skin tissues, toxin production results in local edema. This route of infection has the following stages of development:

- Initial pruritic macule or papule
- Spherical ulcer, sometimes with 1- to 3-mm vesicles around periphery
- Black, painless, depressed eschar, usually associated with extensive local edema

- Lymphadenitis and painful lymphadenopathy can occur with associated systemic symptoms

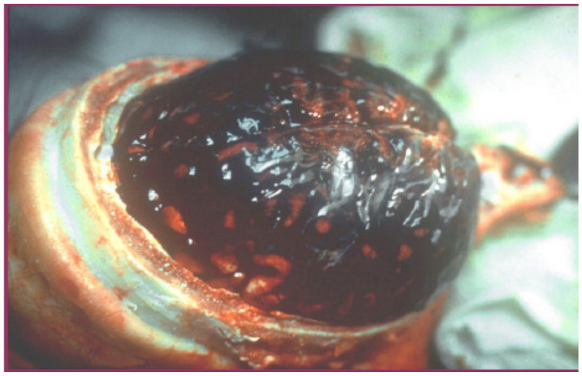
In severe cases where the blood stream is invaded the disease is usually fatal. Without treatment, an estimated 20 percent of cutaneous anthrax can proceed to this condition.

Gastrointestional anthrax

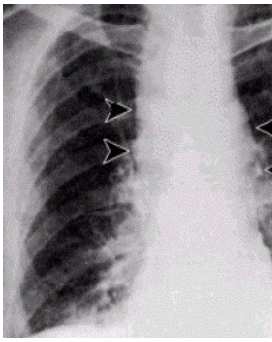
From the University of Alabama website: Gastrointestional anthrax (LD_{50} several hundreds of thousands of spores) occurs as a result of germination of anthrax spores deposited in the upper or lower gastrointestinal tract. Depending on the focus of infection, this can result in either the oropharyngeal (upper GI tract) or ileocecal form (lower GI tract). In the oropharyngeal form, an oral or esophageal ulcer leads to the development of regional lymphadenopathy, edema, and sepsis. The ileocecal form leads to partial necrosis of the intestinal tract, resulting in bloody diarrhea, acute abdomen, ascites, or sepsis.

Photos of tissues damaged by anthrax are readily available from several Internet sources, probably the best ones at http://www.emergency.cdc.gov/agent/anthrax/anthrax-images/cutaneous.asp.

Cutaneous anthrax, small forearm lesion on day 7 after exposure, vesiculation and ulceration of initial macular or popular skin lesion, usually painless at this stage but may be itchy. Photo from CDC website.



Inhalation anthrax, top of head cut away showing brain after death of patient. Photo from http://www.anthrax.osd.mil/documents/1002AvipIndividualbrief.pdf.

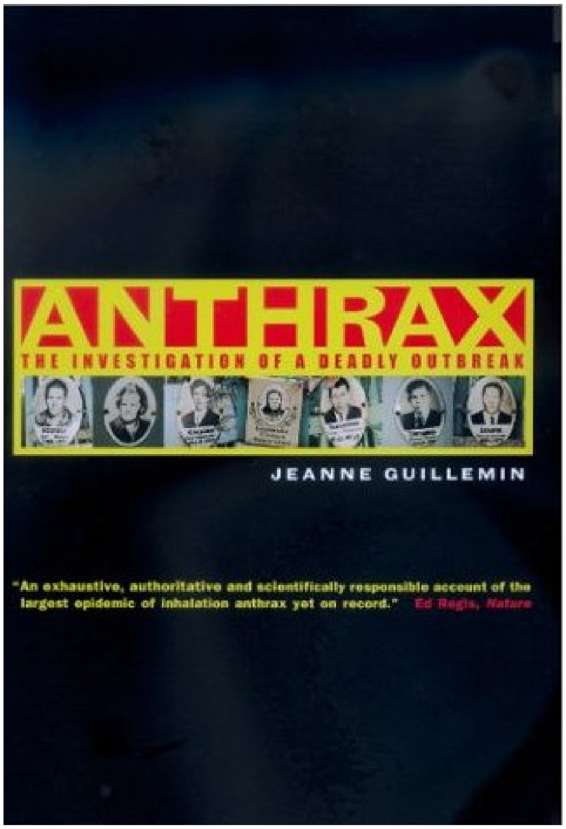


Inhalational anthrax, Lun
showing mediastinal wid
photo from Wikipedia we
from http://www.answers
Additional photos at the U
of Vermont website cited
from the American Medi
association, JAMA 1999

Aggressive and prolonged treatment with antibiotics must begin before symptoms occur, and preferably within 24 hours of exposure. The time of onset of symptoms may vary considerably between individuals and spore dose. The usual treatment for adults (including people with compromised immune systems) is one gram daily (usually two 500 mg tablets daily) of Cipro for 60 days. Other antibiotics can be used, and direct IV administration of antibiotics may be necessary. The treatment might also include administration of a vaccine effective against toxins shortly after exposure. Details on diagnosis and treatment are available at several government websites.

U.S. and British Servicemen stationed in Iraq and Afghanistan are immunized against the toxins produced by the Anthrax bacteria (a protective antigen type vaccine), which offers temporary protection unless an annual booster shot is given. The FDA-licensed BioThrax vaccine (also called AVA, "Anthrax Vaccine Adsorbed" is administered in six-dose steps plus an annual booster shot. The Soviets have developed a live spore vaccine which has serious side effects.

Accidental 1979 Release of Anthrax spores from a Soviet Weapons Plant



The University of California Press in 2001 published a book titled "Anthrax. The Investigation of a Deadly Outbreak" written by Jeanne Guillemin. She was part of a team of professors from Harvard University, Massachusetts Institute of Technology, and Boston University who visited Russia in 1992 to investigate the release of anthrax in April 1979 at a military plant in Sverdlovsk (later renamed Yaketerinburg). The investigation included interviews with many people. The book is available from Amazon.com. The Soviet Union initially denied the release saying that affected persons ate contaminated meat and died. It was later found out that the Soviet Union as part of their Biopreparet program from 1972 to 1993 produced tons of anthrax spores and readied them for use on intercontinental missiles, and that there was an accidental release in 1979. The exact number persons who died or became infected may never be known, but the book cited approximately 68 persons who died of inhalation anthrax and 11 survivors.

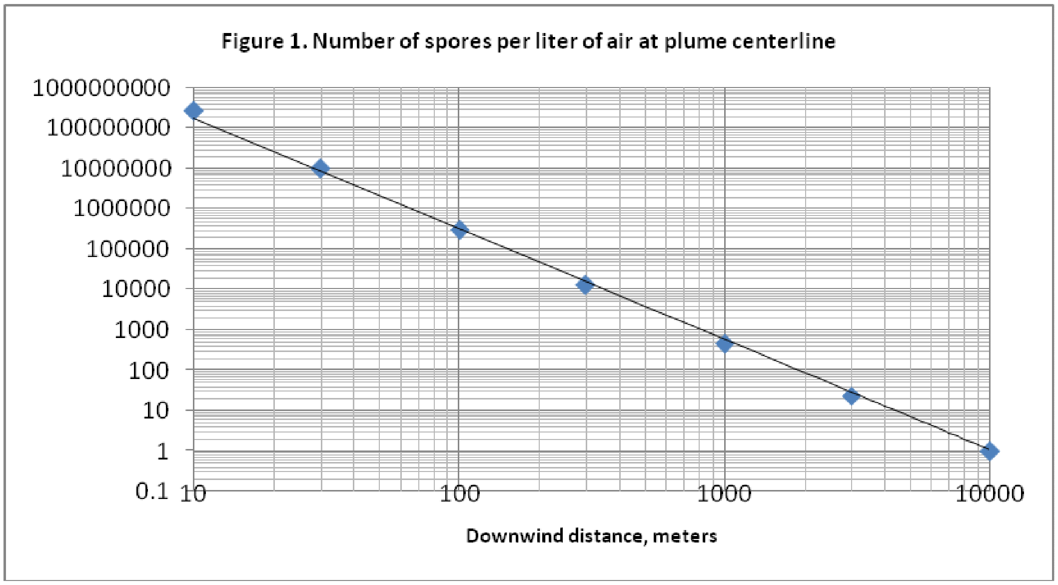
Of interest to plume modelers is an overlay in this book of residences/locations of the people who died of anthrax on a general map of the area. The locations matched what would be predicted from a plume approximately 0.8 km wide and 5 or 6 km long., with higher concentrations closer to the military facility. Only a few death locations were mapped outside the predicted plume, and it is possible the persons could have been within the boundaries but lived elsewhere, or people or vehicles could have spread some spores. A copy of this map overlay and commentary are available at http://www.fahc.org/Healthcare_Providers/Healthcare_Providers_Contribution/Bioterrorism_Curriculum/Email_4_April_14.pdf.   [There may be a copyright issue so we are not reproducing it in this newsletter]. The website comments that weaponized anthrax spores milled to <5 micrometers in size and coated to prevent static clumping would tend to remain suspended in air, and could travel for distances up to 50 miles. This size would also allow the spores to be inhaled deeply into the alveoli spaces of the lungs. The website also commented that the onset of inhalational anthrax symptoms for the people who died occurred up to 43 days after exposure, which was also consistent with monkey exposure tests.

Hypothetical Modeling of an Anthrax Spore Release

We conclude that dispersion models can be used to model a terrorist anthrax spore release, but unlike a chemical release there are more unknowns. A reasonable assumption that the "worst case" is modeled, that the anthrax spores have been weaponized and that the terrorist has figured out a way of dispersing the spores to the atmosphere. A "worst case" modeling might assume a particle size less than 5 micrometers and not include a depletion factor due to particulate settling. A major unknown is the initial number of viable spores released to the atmosphere. An actual terrorist release could result in a later collection of many samples taken downwind and working backwards to estimate the number of spores released. Bacteriologists working with samples might report results as "number of colony forming units per unit weight or volume of sample", meaning that the samples are plated out on a nutrient agar media according to established dilution procedures and the number of bacterial colonies counted after a specified period of incubation. The assumption is made that one bacterial colony corresponds to one "particulate" which may contain one or more viable spores. Colonies resulting from non-anthrax spores (naturally occurring) would also appear on the nutrient agar media complicating the count.

In this hypothetical example, we will assume that 10^{11} weaponized anthrax spores (one gram) is released to the atmosphere during a very short period of time (a "puff" release), and that the particulate dispersion calculations can be approximated by a Gaussian-type dispersion with no depletion factor. We will express downwind concentration units as "number of spores per liter of air". Models in the public domain used by responders (such as ALOHA, the PEAC tool, or models upon which the Emergency Response Guidebook was based, etc.) require the user to specify a chemical and results are in "parts per million" or "mg/m^3", so we will need to revisit some defining algorithms to get things into a format useful for modeling the dispersion of anthrax spores. To avoid complexities resulting from daytime ground heating or nighttime cooling condition, we will assume a neutral atmospheric condition. We used the algorithms published in the DEGADIS manual [available as EPA report EPA-450/4-89-019] as the starting point with 10^{11} colonies as the "mass released", and 18.3 second concentration averaging time [the default time listed in the DEGADIS manual]. There are other algorithms in the public domain that could have been used; the DEGADIS algorithms happen to be power functions which means that the plot as a straight line on a log-log graph (figure 1).

The calculations (figure 1) give a concentration of spores in the air as a function of downwind distance for a person located at the centerline near ground level (the worst location) based on the DEGADIS manual. The concentration drops off to less than one spore per liter at distances greater than 10 km (6.2 miles). But we still don't know the dose (total number of spores inhaled). We have to know the breathing rate and how long the anthrax cloud stays at a particular downwind distance. We also need to specify a wind speed.



A typical breathing rate might be 7.5 liters/minute for an adult at rest and 20 liters/minute for an adult doing light work, and maybe 50 liter/minute under strenuous conditions. We will look at a wind speed of 5 meters/second, and assume that the anthrax cloud is also travelling at 5 meters/second, and use 20 liters/minute as the breathing rate. The time that a person remains in the cloud increases with downwind distance. We will also ignore any eddies that may form due to buildings or terrain, or other situations that might cause the anthrax cloud to linger. The result is figure 2.

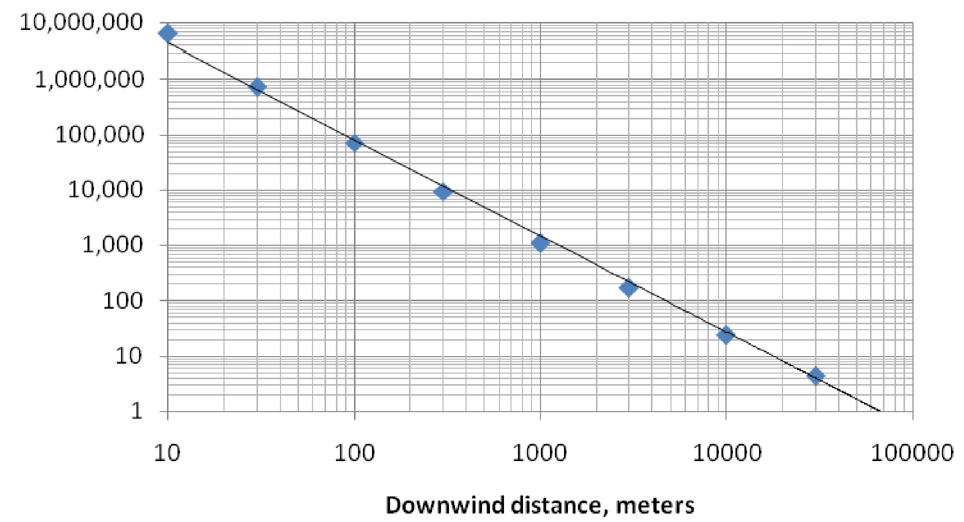


Figure 2. Total number of spores inhaled at plume centerline

If we are looking at a lower limit of LD_{50} of 2500 spores for persons with intact immune systems, we are probably looking at about 1 km (0.62 miles) downwind. But some individuals especially the elderly or persons whose immune systems are depressed could become ill at a much lower dose. A major problem is that treatment must be initiated before symptoms occur, and the inhalation form of the disease is close to 100% fatal if untreated.

Cleanup

Chlorine dioxide was used in government buildings following the 2001 anthrax spore contamination. The chemical must be made up on site.

The U.S. EPA has approved a bleach solution made up of one part household bleach, one part vinegar, and eight parts water. The treated surface should be in contact with the bleach solution for one hour (repeated applications may be necessary to keep the surface wet). The household bleach should first be diluted with some water, then the vinegar added, and additional water added to achieve the recommended proportions.

Some specialized foams and sprays have been developed since the 2001 cleanup, which are easier and less costly to deploy than chlorine dioxide.

This topic is further reviewed in www.answers.com under anthrax.