Technical Discussion

Aerosols and Dusts

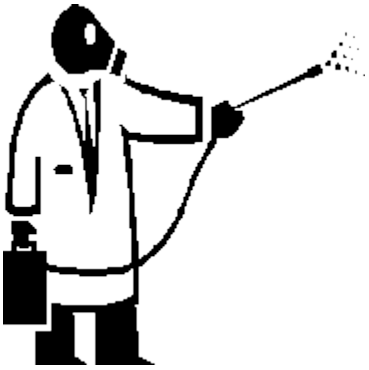
by Dr. John S. Nordin, Ph.D.

The Problem

Many dangerous substances can disperse in the air as a dust or aerosol which is inhaled or may contaminate skin or food and water. ALOHA and the PEAC tool use gas dispersion models to predict a Protective action Distance based on a downwind concentration in the atmosphere. This methodology works well for an industrial accident where a volatile or toxic gas is released out in the open. If an aerosol or fine dust becomes airborne out in the open, the same gas dispersion models usually can be used---if the aerosol or dust particles are fine enough and do not interact with the air. This is not always the case, as releases can occur inside buildings or dusts and aerosols can settle. In the case of a terrorist activity, many other issues must be considered.

Keep in mind that there are many types of aerosols and dusts and many ways for the aerosols and dusts to get into the air.

Definitions



An aerosol is basically minute liquid droplets, the diameters of the droplets are small enough that tiny droplets remain suspended in the air and do not readily settle out. "Dust" is particulate matter, and as it's name implies, is in solid (rather than liquid) form. The distinction can be blurred, for example, aerosols may contain solid matter. Bacteria including anthrax spores might be in aerosols or dusts. Gaseous metals might be generated during a fire, but then condense as mists or fine solid particulates as they contact the cooler air.

The terms fumes, vapors, and mists are used for chemicals or substances whose normal boiling temperature is greater than the ambient temperature but the chemical is mixed in the air and behaves for all practical purposes like a gas. The distinction between a vapor and a mist may be somewhat arbitrary, but the vapor can be thought of as a gas and the mist as minute liquid aerosols suspended in the air. The condensed phase of metals in the air is a metal fume; again this material (which usually is a solid) is too fine to settle out of the air.

What do we mean, "Dangerous Dusts and Aerosols"? We will consider the problem in two parts: (1) industrial accidents (including explosions and fires) and (2) terrorist activities.

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1. Sudden Release of a Cryogenic Liquid

A cryogenic liquid is a chemical that is normally a gas at room temperature but is liquefied under pressure. The liquid is stored in a tank or other container under pressure. The tank

may or may not be refrigerated. Examples of cryogenic liquids are chlorine, anhydrous ammonia, fluorine, and hydrogen fluoride. Of course these chemicals can be stored under pressure as a gas, but if the pressure is great enough or if the chemical is refrigerated, the chemical will liquefy. A much greater amount of chemical can be stored in a tank as a liquid than as a gas because the density of the liquid is greater than the gas.

What happens if a hole is punched in the tank or a connecting valve or pipe is sheared off? The pressure inside the tank is suddenly released. The liquid inside the tank boils. Gas and liquid escape rapidly out the tank hole or sheared pipe. Depending upon the dynamics, the liquid escaping from the hole or pipe could be in the form of an aerosol or fine droplets. Some of the droplets may settle forming a liquid pool near the opening. If the droplets are small enough, they will be carried as an aerosol with the escaping gas. When the tank pressure is released and the liquid evaporates, the air around the hole will chill. The cold air containing the aerosol will tend to settle near the floor (ground) and spread out from its source.

2- Dust

Dust can be released from explosions, including the collapse of buildings and structures. Weather conditions may blow dust from the ground. There are environmental laws on the books that limit fugitive emissions.

3- Fires

Industrial fires, especially those involving chemicals, can release many particulates to the atmosphere.

Terrorist Activities

1- "Dirty Bomb"

A “dirty bomb” is the purposeful release of radioactive isotopes into the environment. A terrorist may strap a container of a radioactive isotope in powder form to a conventional explosive and detonate the material. The radioactive isotope could also be dissolved or slurried in liquid form. The setup of such a device would probably be very risky to the terrorist as the handling of any radioactive material is very dangerous. If the “explosion” results in minimal damage or if lead shielding is found at the explosive site, this is a tip-off. A car bomb could also be seeded with radioactive material. Confirmation is made by using radioactive detection equipment.

2- Chemical Warfare Agents

The PEAC tool contains a menu where the user can pull up a screen listing many chemicals which may be used as chemical warfare agents. Some are common industrial chemicals such as phosgene and hydrogen cyanide which serve many legitimate uses. Others such as Sarin and VX have no legitimate use and are banned by the international chemical weapons

treaty. Some are very odorous and choking but others may have a mild pleasant odor or odorless and could easily be inhaled or applied to the skin with the person unawares. One drop of VX applied to intact skin is sufficient to kill.

A terrorist using such a weapon must find a way of getting the chemical agent into the air where it might be inhaled or contacted with the skin as from contaminated clothing. One way is setting off an explosive device by a container of the material. Another way is using a small pressurized tank dispersing as an aerosol. There is concern that crop dusting equipment on small planes could be used.

The United States once had a military program which included the development of binary weapons. Two chemical components each of which was relatively benign when mixed together form Saran or VX. The mixing was done in a delivery bomb) dropped from the air. The military D2PC model had a component which predicted downwind dispersion and nearby ground spray of chemical agents delivered by several different kinds of bombs. Depending upon the bomb and height and the chemical, different portions of the agent might be sprayed on the ground or remain airborne and travel downwind.

Rouge governments potentially may invest in technologies which allow the chemical agent to be more easily handled, or smuggled, or dispersed into the air. The chemical warfare agent might be mixed with a carrier solvent or adsorbed onto a fine powder for dispersion as an aerosol or dust. The technologies are the same as those employed for pesticide application or even in the food processing industry. For example, there has been recent concern on the part of the U.S. military that Iraq may have developed a VX powder, where the VX chemical is adsorbed unto a fine silicon dioxide "mists" roughly on the order of 0.01 microns (or less) in diameter, which may allow the chemical to be inhaled as a gas. The chemical VX in its pure form is a very viscous liquid with a very low vapor pressure, and is not easily inhaled.

3- Biological Warfare Agents

The news has focused attention on powders containing anthrax spores delivered in letters addressed to people in government. Some of the spores apparently escaped the letters as a few postal workers developed inhalation anthrax. Anthrax spores are very resistant to drying and sunlight, and may remain infectious for years, even decades. Roughly 8000 to 50000 spores are required to infect a healthy adult by inhalation, but the dose for the elderly could be much less. Anthrax is not contagious with normal human contact.

Tularemia or rabbet fever is normally transmitted to humans by infected flies, mosquitoes, or ticks. Rabbits and other small animals might serve as the host species in nature. Only a few tularemia bacteria, perhaps 10 or less, can infect a human. The bacteria can live for weeks even months in contaminated dust outside the infected insect or animal. This property makes it possible for a dangerous dust containing the bacteria to be produced from animal or insect parts or excrement. Inhalation tularemia has a higher fatality rate than if acquired through an insect bite.

There are a number of viral and bacterial diseases that are normally transmitted through the bite of a tick or by inhaling dust containing excrement or saliva of infected rodents. Infected ticks and their droppings can be ground to produce an infectious dust which may be inhaled. They have potential for producing a bioterrorist weapon. Some viruses and bacteria do not live outside the host long and are susceptible to drying. Other dusts may remain infectious for many months, depending on the agent and how it is preserved.

Small pox is a highly contagious disease for which there is no cure. It is most contagious when the initial rash develops. Transmission is by direct contact or indirectly through contact through objects that an infected person has also contacted (e.g. the phone, money, papers, etc.). It can also be spread in a confined area by inhalation. Fortunately, the virus does not survive very long outside the human host, but still can be infectious for hours. The infected terrorist himself might serve as the dispensing agent.

So Why not Model the Release?

There are many ways for aerosols and dusts to be released. A terrorist may release the dust or aerosol in a building or airplane or subway. There are models available for specific applications such as the release of hydrogen fluoride or a chemical warfare agent released as a gas out in the open. If the aerosol or dust is fine enough, it will behave as a gas and a gas model can be used to estimate a downwind concentration.

Gas dispersion models would be almost useless in predicting downwind dispersion in release of biological weapons, especially if only a few organisms can infect a person. The release also might take place inside buildings or other confined areas. The release quantity would probably be unknown.

When an industrial or transportation accident occurs, the chemical released and perhaps even the quantity is known (at least the tank size is known). There is probably an appropriate gas dispersion model that can be used. With a terrorist activity, the material released and quantity is unknown.

More important to the first responder is to establish that an incident has taken place, and what the material is. What can be done to protect the public and emergency personnel? How long will the location be contaminated? Individuals exposed to the contamination will need to be located and tracked down to make sure they do no spread the contamination, whether the contamination is a radioactive isotope or a communicable disease or a chemical warfare agent. Persons exposed to contamination may need to be isolated in addition to being treated. There is also the matter of decontamination and cleanup. These issues will likely take center stage.

Establishing that a Terrorist Incident has Taken Place

Any suspicious explosion should be checked for radioactivity. Any package unusually heavy for its size should also be checked for radioactivity. A person exposed to a lethal dose of radiation or a chemical warfare agent or to a deadly disease may feel fine at the moment but later die a horrible death.

Sometimes the first clue that an incident has occurred is when a large number of people become sick, especially with similar symptoms. A single case of an uncommon disease should also be investigated. Epidemiologists and law enforcement officers need to work closely on this. The Military Medical Technology (volume 6 issue 8, 2002, pages 32-34) has published a number of questions law enforcement officers and epidemiologists should ask when investigating an illness/sickness outbreak. These are repeated here. Epidemiology is the study of the incidence and distribution of diseases in large populations, and the conditions influencing their spread and severity.

Questions Law Enforcement Officers Might Ask (from Military Medical Technology, with additions):

1. What do you think made you ill?
2. When did you start feeling sick (date/time)?
3. Do you know of anyone else who became ill or died?
4. Have you had any medical treatment in the last month? What is the name of your health care provider? Where were you treated? Are you taking any medications?
5. Where do you live and work (or go to school)?
6. Did you attend a public event? (Sporting event, social function, restaurant, etc.). What did you eat there?
7. Have you or your family members traveled more than 50 miles in the last 30 days?
8. Have you or your family members had any contact with an individual who has been in another country in the last 30 days?
9. Have you seen anyone with an unusual device or anyone spraying something? Anyone with laboratory equipment or other suspicious activities? These questions might in particular be asked in context of a public event or a location where the public may assemble.
10. Have you detected any unusual odors or tastes?
11. Have you noticed any sick or dead animals or birds?

This information should be provided to public health officials.