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Particles Are Tiny, but Damage Can Be Great
By JAMES GLANZ

Until anthrax spores started spreading through the mail, few people gave much thought to the minuscule particles that drift almost invisibly in the atmosphere, infiltrate buildings and plunge deep into lungs. Not so for environmental scientists, who have spent decades studying the physics and physiology of particles very much like those in the most dangerous forms of biological weaponry.

From the coal dust that causes black lung disease to the bacteria−laden droplets that spread Legionnaires' disease to second−hand cigarette smoke and plain old air pollution, particles from about 0.05 microns to 10 or 20 microns in size have long been at the focus of those scientists' attention. A micron is a millionth of a meter, or an inch divided into 25,400 parts.

Those tiny particles crop up in environmental science and germ weaponry for virtually identical reasons. Once released, particles of that size can stay aloft almost indefinitely and seep into poorly sealed buildings, greatly increasing the chances of the particles' being inhaled by people.

What is more, the peculiar microscopic physics shared by all those particles makes it certain that some of them, within a highly specific range of sizes, will be able to slip past protective nose hairs, avoid sticky bronchial walls and be deposited in the deepest reaches of the lungs, where great damage can be done.

"A particle is a particle," said Dr. Joe Mauderly, a toxicologist at the Lovelace Respiratory Research Institute in Albuquerque, where he is director of the National Environmental Respiratory Center.

What pathogen the particle may be carrying has almost nothing to do with where it ends up. "The fact that this is a biological issue doesn't really change the behavior of the particles in the building, or the respiratory deposition," said Dr. William Nazaroff, a professor of environmental engineering at the University of California at Berkeley.

Once the particle does land, its exact composition \227 whether it is harmless, chemically toxic or biologically infectious \227 comes very much into play. Of course, much is known about that process too, especially through studies of Legionnaires', tuberculosis and other bacterial diseases that are transmitted through the air on particles that are, not coincidentally, a few microns in size.

The existence of all this knowledge, freely available in unclassified literature, is double−edged, the scientists say. It may sap germ warfare of some of its mysteriousness, but it also shows how widely available much of the information needed to design the weaponry is.

For many environmental scientists, who in recent years have been warning that pollution particles of that size pose a special danger to human health if they come indoors, the bioterrorism threat is one more reason to improve the quality of indoor air with powerful filters and other methods.

That proposal, like any that could lead to new regulations on industry, is bound to be controversial, especially since buildings have been constructed to be less leaky to outside air and ventilation systems have been improved in recent years. So some researchers are suggesting that further improvements be voluntary. "We should get the insurance companies to lower your life insurance slightly if you have approved equipment," said Dr. Matthew S. Meselson, a professor of biology and bioweapons expert at Harvard.

Specific health effects aside, what is not controversial is the physics of the tiny particles. Human airways act as a kind of sorting machine to allow only particles of certain sizes to reach the deepest part of the lungs \227 the breathing sacs, or alveoli.

The bronchial tubes of the lungs have a treelike structure, branching from a few airways that are centimeters wide at the top to millions of smaller ones, each a fraction of a millimeter across, deep in the lungs. At the end of each branch are tiny alveoli, each perhaps 50 microns across, said Dr. Charles H. Hobbs, director of toxicology at Lovelace.

"You could just barely see them," Dr. Hobbs said. "It’s half the size of a human hair."

The total surface of area of those little sacs, where blood capillaries exchange oxygen for carbon dioxide, is roughly the same as that of a tennis court. And a particle’s fate is generally very different depending on whether it rides an airstream all the way to an alveoli or hits the wall of a bronchial tube before then.

That is because the bronchial walls are coated with mucus and ciliary, or hairlike, cells. Any particle that strikes the wall gets stuck, and a wavelike motion of the cilia can move it back up the tract like an escalator to the mouth. There, the particle is swallowed and digested.

"Once a particle is swallowed, it’s as if you ate it instead of breathed it," said Dr. Mauderly of Lovelace. "You do this all the time and are never aware of it."

But a particle that makes it all the way to the alveoli can, under the right circumstances, cause more mischief. Each sac is often guarded by a single scavenger cell, or macrophage. There, a bit of coal dust could insinuate itself into lung tissue, potentially leading to a stiffening of the lungs called fibrosis.

Unless the macrophages win their battle, disease−causing bacteria begin doing their damage in the same sacs. It is there, for example, that an anthrax spore would be taken up by a macrophage, which would carry it elsewhere to germinate and begin to produce the toxins that can lead to inhalation anthrax.

"Your lung," said Dr. Morton Lippmann, a professor of environmental medicine at New York University medical school, "is a very good culture medium \227 you can get enormous replication and damage to the lung."

To have that chance, the invading particles must avoid destruction at the hands of the ciliary escalator. Whether they succeed depends not on their biological potency or chemical toxicity, but largely on their size.

Relatively large particles like pollen are stopped almost before they begin the journey. Those particles, generally around 20 microns in size, often are stopped by the coarse filter formed by hairs in the nose.

Particles in the next size range \227 say, 5 to 15 microns \227 may slip past the nose and survive farther into the journey once they are inhaled. Fly ash from incinerators and some auto pollution falls into that range.

But those particles eventually have trouble negotiating the increasingly narrow airways. In a process called impaction, the particles can fail to be carried around a sharp corner by an airstream, like a truck that skids on a wet roadway that poses no problem for a sports car. Other particles in that range can be pulled downward by gravity. In either case, the particles hit the walls and are stopped.

However, extremely fine particles, much smaller than a micron, are also stopped high in the system of bronchial tubes. That is because when air molecules strike those particles, they are so small that the impacts knock them into a diffusive dance that eventually ends up, as with any bad dancer, against the wall. What is left is at least one optimum range, roughly between one and five microns, that has a good chance of going all the way to the breathing sacs.

How the particles may spread through a room or building once they are released is no less complex, Dr. Nazaroff said. Consider, for example, the anthrax−carrying letter that was opened in Senator Tom Daschle’s office in the Hart Senate Office Building.

Dr. Nazaroff said that within a minute or two, particles released from the envelope could be spread throughout the air in the room by processes most people are scarcely aware of. Plumes of warm air are constantly rising off people, who in that respect are "roughly equivalent to a 75−watt light bulb," he said. Other currents driven by ventilation or temperature variations near window help spread the particles.

The ventilation system can help spread particles, too. Air often is blown directly into offices from vents, but is drawn away through intake vents in the hallways, Dr. Nazaroff said. That means the particles can migrate down halls and into nearby offices before being sucked in, or even slip straight through walls if there are tiny air pressure differences in adjacent offices. Those processes could explain why two workers in an office next to Mr. Daschle’s later showed evidence of exposure.

Outside of the specific pathogen involved, the physics of how particles of any kind float in air and soar through the lungs explains much about biological weapons.

"In a nutshell, the particles not only have to be small," said Richard Spertzel, a former weapons inspector and biologist for the United Nations Special Commission on Iraq. "They have to be small enough so that they are capable of staying airborne, and also they have to be small in order to get down into the lungs."