Incineration of anything, including garbage and hazardous chemical wastes, produces a kind of pollution that is uniquely dangerous to humans: fine particles.

In this series, we will first discuss the characteristics of fine particles, and later we will discuss health studies showing the consequences of breathing fine particles.

The process of incineration turns solids and liquids partly into gases and partly into tiny particles of soot or ash. As the gases rise in the smoke stack, they cool and some of the gas molecules come together to form additional fine particles. The resulting particles are exceedingly small when they are emitted into the environment. Scientists who study particles make a distinction between coarse (large) particles and fine (small) particles. Fine particles behave entirely differently from coarse particles and, as we will see, are much more dangerous to humans. Fine particles are also much more difficult and expensive to control. They are also invisible, so when they are not controlled, there is no way to know it except by monitoring with the proper instruments.

Coarse particles are those with a diameter larger than 2 micrometers (um); fine particles are those with a diameter less than 2 micrometers. A micrometer (um) is a millionth of a meter and a meter is about a yard. (An older term for micrometer is micron.)

Incinerators emit large numbers of particles, despite the best available control technology. Half of all the particles emitted will have a diameter less that 2 um, and the majority of these will have a diameter of 0.3 um.

It is difficult to imagine how small these particles are. To help understand what we're talking about, look at the dot over the letter i in this newsletter; that dot measures about 400 micrometers in diameter. You can fit 40,000 particles with a diameter of 2 um on the dot. When the particles have a diameter of 0.3 um, you can fit 1.7 million particles on the dot over the i.

Unfortunately, U.S. EPA (Environmental Protection Agency) regulations do not take into consideration the sizes of the particles emitted by an incinerator. For regulatory purposes, coarse particles are considered to be the same as fine particles, as if they were all equivalent. The regulations issued as part of the Resource Conservation and Recovery Act (RCRA) allow the emission of 0.08 grains per dry standard cubic foot of stack gas (or 180 milligrams per dry standard cubic meter). There are 437.5 grains in an ounce.

Measurements show that half these particles will have diameters ranging from 2.5 down to 0.1 micrometers; of that half, a majority will have a diameter of 0.3 micrometers. If we assume that 25% are 2 um, 25% are 1 um, 35% are 0.3 um and 15% are 0.1 um in diameter, we can generalize about the fine particle emissions from an incinerator.

Each pound of fine particles emitted from an incinerator will consist of 140 quadrillion (1.4 x 10 17) individual particles. A quadrillion is 1000 trillion. Over a year's time, an incinerator meeting the federal standards will legally emit anywhere from 10 to 1000 TONS of fine particles, depending upon the size of the incinerator.

Breaking things into fine particles has the effect of vastly increasing their surface area. A single lump of weight weighing a pound (and having the same density as water) would have a surface area of about 44 square inches (a square 6.5" on a side), about the size of a large post card. But when that same pound is broken into fine particles, its combined surface area grows to 9900 square yards (approximately two football fields).

This is important for several reasons: as these fine particles move upward in the smoke stack, they are immersed in a bath of gaseous chemicals that are cooling and are "looking" for a place to turn from a gaseous to a solid state. Fine particles, with their large surface area, provide an inviting place, and so the surfaces of fine particles become covered with pollutants ("enriched" is the technical term for this) before they are released into the local air. In particular, fine particles become coated with toxic metals (lead, cadmium, arsenic, chromium, and zinc, and with sulfur and polycyclic aromatic hydrocarbons—or with whatever else is in the smoke stack).

As the human body evolved throughout its long history, it adapted to the environment. One factor in the environment has always been dust, principally from dust storms. Dust from storms is larger than 5 um in diameter and the human body evolved mechanisms for protection against such large particles. The hairs inside the nose, the mucous membranes lining the nose, throat and lungs, and even the shape of the throat, help to trap dust. As air is inhaled, the shape of the throat causes the air to swirl, so heavy dust particles are thrown outward by centrifugal force, where they strike the mucous-lined walls. As the tubes and passageways leading to the lungs twist and branch, they provide many opportunities for particles to collide with sticky walls and become trapped before they enter the lungs. Once trapped by mucous, coarse particles are coughed up and excreted.

Nature has gone to great lengths to protect the lungs because the deepest regions of our lungs provide places (called alveolar sacs, or alveoli) where oxygen passes into the blood and carbon dioxide passes out of the blood. The lungs provide a large surface area for contact with air, and thus with fine particles; the surface area of the alveoli is 65 square yards, which is larger than two tennis courts.

Thus, the deep regions of the lung provide direct access to the blood stream and, by this means, to every part of the body.

Unfortunately, humans now produce huge numbers of fine particles that elude the body's protective mechanisms entirely. Fine particles pass easily into the deepest regions of the lungs, the alveoli, or alveolar sacs. There they remain indefinitely because no clearance mechanisms effectively remove them. Nature did not protect us against such particles, because none existed until very recently.

Once lodged in the deep regions of the lung, fine particles, with their enormous surface area enriched with toxics, provide a particularly efficient means for delivering metals and organic pollutants directly into the blood stream. Their large surface area provides effective contact with moist tissue and the opportunity for dissolved or for other chemical reactions, putting pollutants directly into the victim's blood. Once in the circulatory system, toxics are then distributed throughout the body.

[Tobecontinued.]

--Peter Montague

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The best books on fine particles are those of the National Research Council, National Academy of Sciences: AIRBORNE PARTICLES (Baltimore, MD: University Park Press, 1979) and CONTROLLING AIRBORNE PARTICLES (Washington, DC: National Academy of Sciences, 1980); a short summary appears in FINE PARTICULATE POLLUTION, A REPORT OF THE UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (Amsterdam and NY: Pergamon Press, 1979). A good, though very technical, introduction is William Hinds, AEROSOL TECHNOLOGY: PROPERTIES, BEHAVIOR AND MEASUREMENT OF AIRBORNE PARTICLES (NY: John Wiley and Sons, 1982). Incineration of anything, including garbage and hazardous chemical wastes, produces a kind of pollution that is uniquely dangerous to humans: fine particles.

Descriptor terms: particulates; air pollution; air quality; incineration; epa policies; rcra; emissions;