Aerosols: Tiny Particles, Big Impact

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Take a deep breath. Even if the air looks clear, it's nearly certain that you'll inhale tens of millions of solid particles and liquid droplets. These ubiquitous specks of matter are known as aerosols, and they can be found in the air over oceans, deserts, mountains, forests, ice, and every ecosystem in between. They drift in Earth's atmosphere from the stratosphere to the surface and range in size from a few nanometers—less than the width of the smallest viruses—to several several tens of micrometers—about the diameter of human hair. Despite their small size, they have major impacts on our climate and our health.

Aerosols—tiny, airborne solid & liquid particles—are present throughout the atmosphere and largely responsible for hazy skies, as in this photograph of Shenzen, China. (Photograph ©2010 pseudo-san.)

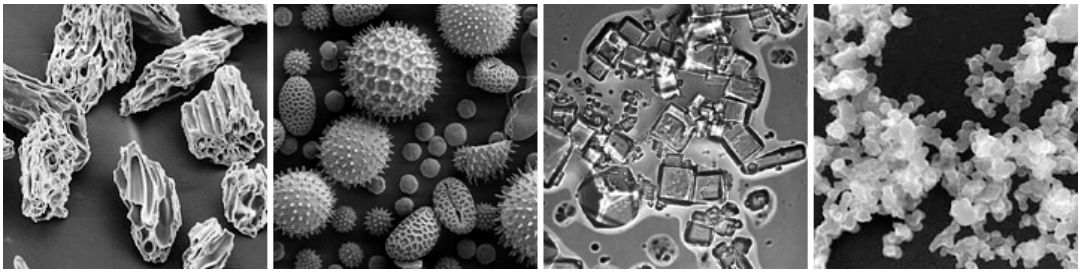
Different specialists describe the particles based on shape, size, and chemical composition. Toxicologists refer to aerosols as ultrafine, fine, or coarse matter. Regulatory agencies, as well as meteorologists, typically call them particulate matter—$PM_{2.5}$ or PM_{10}, depending on their size. In some fields of engineering, they're called nanoparticles. The media often uses everyday terms that hint at aerosol sources, such as smoke, ash, and soot.

Climatologists typically use another set of labels that speak to the chemical composition. Key aerosol groups include sulfates, organic carbon, black carbon, nitrates, mineral dust, and sea salt. In practice, many of these terms are imperfect, as aerosols often clump together to form complex mixtures. It's common, for example, for particles of black carbon from soot or smoke to mix with nitrates and sulfates, or to coat the surfaces of dust, creating hybrid particles.

Sea salt, dust, and volcanic ash are three common types of aerosols. (Photograph by Katherine Mann.)

The bulk of aerosols—about 90 percent by mass—have natural origins. Volcanoes, for example, eject huge columns of ash into the air, as well as sulfur dioxide and other gases, yielding sulfates. Forest fires send partially burned organic carbon aloft. Certain plants produce gases that react with other substances in the air to yield aerosols, such as the "smoke" in the Great Smoky Mountains of the United States. Likewise in the ocean, some types of microalgae produce a sulfurous gas called dimethylsulfide that can be converted into sulfates in the atmosphere.

Sea salt and dust are two of the most abundant aerosols, as sandstorms whip small pieces of mineral dust from deserts into the atmosphere and wind-driven spray from ocean waves flings sea salt aloft. Both tend to be larger particles than their human-made counterparts.



These scanning electron microscope images (not at the same scale) show the wide variety of aerosol shapes. From left to right: volcanic ash, pollen, sea salt, and soot. [Micrographs courtesy USGS, UMBC (Chere Petty), and Arizona State University (Peter Buseck).]

The remaining 10 percent of aerosols are considered anthropogenic, or human-made, and they come from a variety of sources. Though less abundant than natural forms, anthropogenic aerosols can dominate the air downwind of urban and industrial areas.

Fossil fuel combustion produces large amounts of sulfur dioxide, which reacts with water vapor and other gases in the atmosphere to create sulfate aerosols. Biomass burning, a common method of clearing land and consuming farm waste, yields smoke that's comprised mainly of organic carbon and black carbon.

Desert dust, volatile organic compounds from vegetation, smoke from forest fires, and

Automobiles, incinerators, smelters, and power plants are prolific producers of sulfates, nitrates, black carbon, and other particles.

Deforestation, overgrazing, drought, and excessive irrigation can alter the land surface, increasing the rate at which dust aerosols enter the atmosphere. Even indoors, cigarettes, cooking stoves, fireplaces, and candles are sources of aerosols.

volcanic ash are natural sources of aerosols. (Photographs copyright (left to right) Western Sahara Project, Jonathan Jessup, Vox, and Ludie Cochrane.)