# Chapter 1 : Hazards and Concerns of Airborne Particulates

## Particulate Matter

Particulate matter (PM) in the atmosphere is a mixture of solid particles and liquid droplets, many of which are not visible to the naked eye. PM can be directly emitted or formed by chemical reactions in the atmosphere. PM is a concern because it can 1) cause health impacts to humans, plants and animals, 2) degrade visibility, causing accidents on roadways or impairing the view of scenic vistas, and 3) deposit out of the atmosphere causing a variety of impacts including influencing nutrient cycles. Farming, ranching, and forestry operations can all be sources of particulate matter. This chapter is designed to give a brief introduction to PM characteristics and the impacts of PM.

### Particulate Matter Size and Shape

PM in the atmosphere exists in a wide range of shapes and sizes and is made up of a variety of chemical species (for example, carbon, sulfates, heavy metals). PM is classified by its size, where fine particles are the small particles that can be inhaled deep into the lungs. These fine particles are known as $PM_{2.5}$, which are particles that have an aerodynamic equivalent diameter (AED) less than or equal to 2.5 micrometers (µm). The next size class of PM are inhalable larger particles, known as $PM_{10}$, which are particles with an AED less than or equal to 10 µm. Note that $PM_{2.5}$ is actually a subset of $PM_{10}$. Particles are typically not perfectly spherical and instead come in a variety of shapes. The AED is defined as the diameter of a spherical particle with a density of 1 $g/cm^3$ that would have the same settling velocity as the particle in question.[1] Particles with the same AED presumably perform alike when suspended in the air. Particles larger than 10 µm in AED can also be suspended and transported in the atmosphere, however these particles usually settle out rather quickly in comparison to smaller particles. Figure 1-1 shows the relative size of $PM_{2.5}$ and $PM_{10}$ compared to a human hair and beach sand. $PM_{2.5}$ is approximately 30 times smaller than human hair while $PM_{10}$ is approximately 7 times smaller. PM concentration is typically measured on a mass per volume basis ($\mu g/m^3$) but it can also be discussed in terms of particle number. While small diameter particles can have a low mass concentration in the atmosphere, on a particle number basis there can be orders of magnitude more fine particles than larger, more coarse particles.

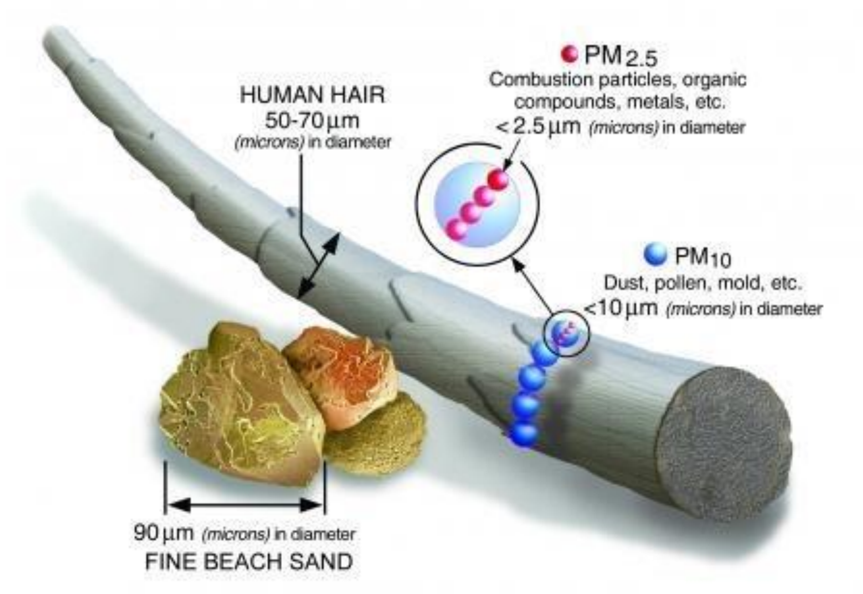


Figure 1-1. Size of $PM_{2.5}$ and $PM_{10}$ relative to a human hair and beach sand.[2]

Fine PM concentrations in the atmosphere can be generated from a variety of natural and man-made sources, and can be comprised of carbonaceous compounds, soil (geologic material) and inorganic species of sulfate, nitrates and ammonium. Coarse PM typically is comprised of geologic dust or soil and often is directly emitted to the atmosphere. Fine PM can be directly emitted or created by physical and chemical processes in the atmosphere (secondary PM). Figure 1-2 shows examples of various types of particles and their typical size distributions. Dust tends to be 1-10 µm while combustion processes mostly produce smaller particles in the 0.01-1 µm range.

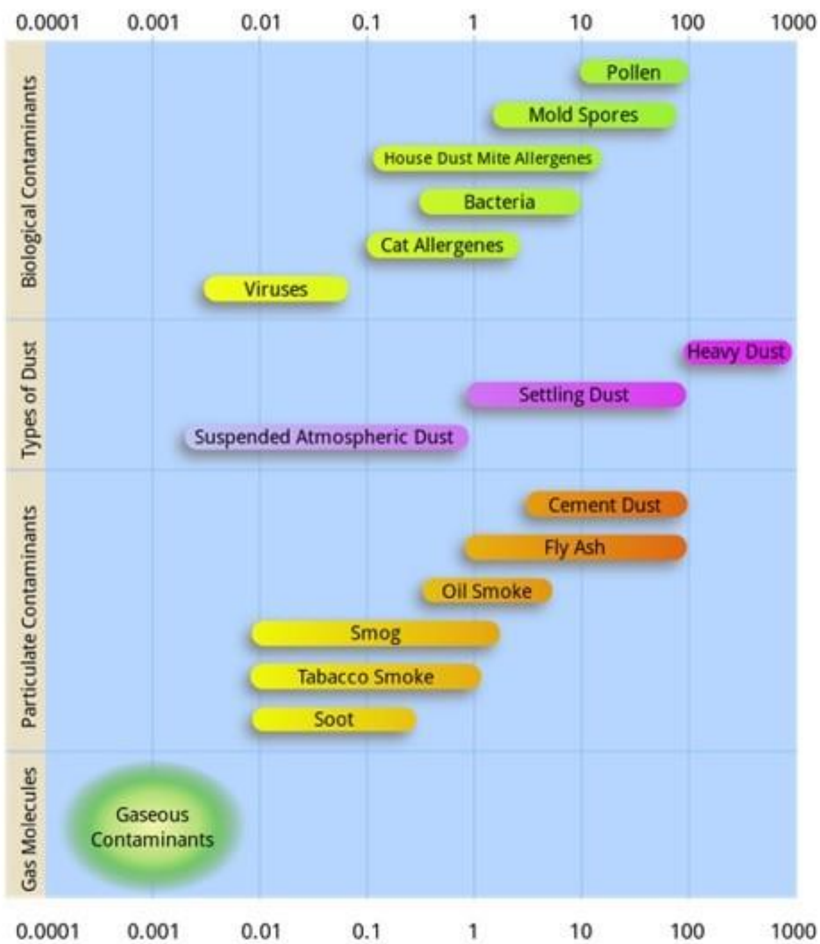


Figure 1-2. Examples of the size distribution of particles emitted from various sources in micrometers (µm).[3]

## Impacts of Particulate Matter

Particulate matter (PM) can cause impacts on local, regional, and even global scales. Larger particulates tend to deposit quickly out of the atmosphere, but can remain suspended long enough to create local visibility reductions and transportation issues (such as on roadways or at airports) and other local impacts. Smaller particles that are either directly emitted or formed by atmospheric chemical processes can stay suspended in the atmosphere for longer periods of time and can therefore be transported greater distances, creating regional, and sometimes even global, health, visibility and deposition impacts.

## Health Impacts

Figure 1-3 illustrates where and how particulates can be removed from or deposited in the human body. While the human body is efficient at filtering out the larger particles (> 10 µm) in the nasal passages, smaller particles on the scale of 5 µm get filtered out in the trachea. Fine particles can progress past the natural defenses into the bronchioles (< 2 µm) and some alveoli (< 1 µm) of the lungs. Once particles enter the lungs, the immune system sends white blood cells, called lymphocytes, to surround the particulates, protecting the body from the foreign objects. The lymphocytes settle on the alveoli walls, causing inflammation and scarring. The built-up scar tissue slows oxygen flow, making transfer of air to capillaries more difficult. This can be of particular concern to sensitive populations such as the elderly and asthmatics.

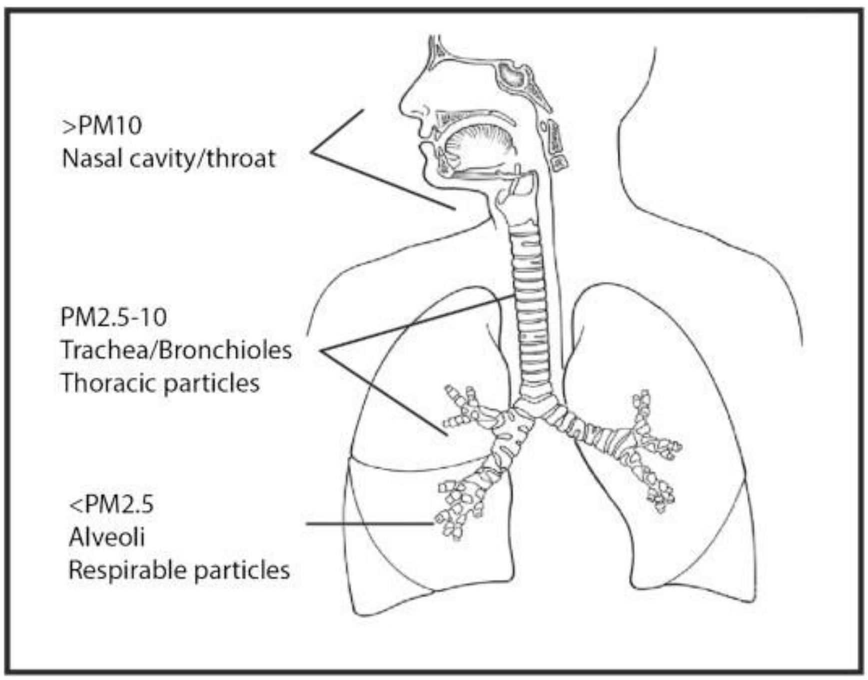


Figure 1-3. Deposition of airborne particulate matter in the human respiratory system.[4]

## Visibility Impacts

PM in the atmosphere can absorb and scatter light, thereby reducing visibility. Episodes of impaired visibility can range in scale from local plumes (e.g., road dust) to widespread regional haze. Increased haze in the atmosphere causes objects to appear "flattened," whitens the background, and degrades the aesthetic value of scenic vistas. For example, the view visibility along Interstate 10 in Cochise County led to road closures in 2016 (Figure 1-4). Visibility can also be a local issue because dust or smoke can decrease the visible range to distances that can be dangerous on roadways, along with other localized impacts.

Figure 1-4. Dust storms in April 2016 in Cochise County forced interstate closures. Courtesy Arizona Department of Public Safety.[5]

## Deposition and Impacts

Deposition is the removal of PM via precipitation, gravitational settling, or inertial impaction and/or absorption due to changes in airflows. Deposition as a result of precipitation is known as wet deposition and occurs through scavenging of the particle by rain, snow, clouds, or fog. Deposition via gravitational settling or inertial impaction is known as dry deposition. Deposition may adversely affect ecosystems by causing nuisance dusting, changing the pH balance, damaging plants or by adding additional nitrogen to the environment, which can result in an increase in eutrophication.

Ecosystems can be sensitive to the effects of deposition. High elevation ecosystems in the Rocky Mountains, Cascades, Sierra Nevada, southern California, and the upland areas of the eastern U.S. are generally the most sensitive to the acidifying effects of deposition due to their poor ability to neutralize acid deposition. Other potentially sensitive areas include the upper Midwest and New England. Acid deposition can also impact agricultural systems by changing the chemical properties of soil, although management of these systems with fertilizers and other soil treatments mitigate this. However, acid deposition can also damage waxy coating on leaves. In addition, many ecosystems are sensitive to the enrichment effects of nitrogen deposition, including those with short growing seasons (i.e., a limited capacity to use available nitrogen) and those that have evolved under low nutrient conditions. Nitrogen sensitive areas include high-elevation ecosystems, arid ecosystems, grasslands, and shallow bays and estuaries along the Atlantic and Gulf Coasts. The transport and deposition of dust and black carbon to the snowmelt dominated basins worldwide are of concern, especially in the springtime where the deposition increases snowpack albedo thereby enhancing snowmelt. Dust can have a physical effect on plants, coating the plant and blocking sunlight necessary for photosynthesis, causing abrasion, and blocking the stomata. Also, a dust coating can affect the intended action of pesticides and other chemicals. Depending on the chemical composition of the dust, its deposition can also alter soil chemistry.