WHITE PAPER

Overview of Particulate Matter

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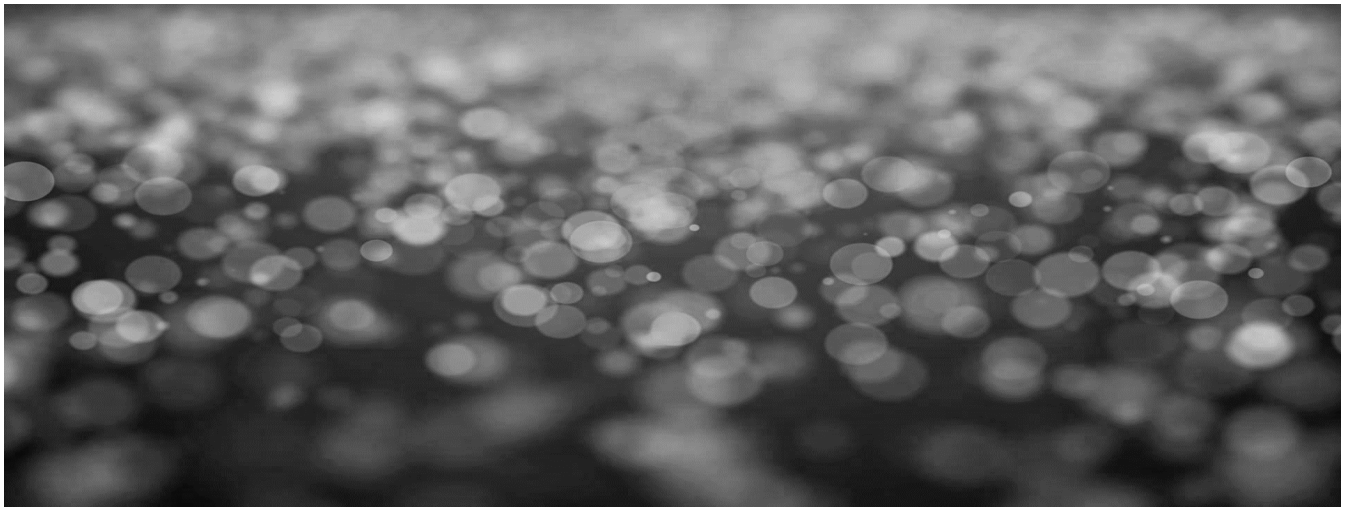

Top Product Innovations Inc P.O. Box 3118 Indian Trail, NC 28079

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An Overview of Particulate Matter

In any indoor or outdoor environment, particulate matter is all around. Depending on the size, type, and exposure length of that particulate matter, this can have negative health effects. Discover the most pressing information about particulate matter, including what it is, how it affects individual and environmental health, and strategies to mitigate it in commercial or residential settings.

What Is Particulate Matter?

Particulate matter can be understood as the sum total of all airborne particles in an environment. It is a broad umbrella that covers either organic or inorganic particles. Particulate matter includes a complex range of particles, comprising both solid particles or liquid droplets suspended in air.

Particulate matter is sometimes referred to by any of the following names:

- Atmospheric aerosol particles
- Atmospheric particulate matter
- Particle pollution
- PM
- Suspended particulate matter

Certain kinds of particulate matter can be seen with the naked eye; others are microscopic. Many (but not all) are hazardous.

Different Kinds of Particulate Matter

Particulate matter is generally broken down into three categories: coarse particles, fine particles, and ultrafine particles.

The distinction depends on particle size, or (more accurately) aerodynamic diameter. This is defined as the "diameter of a sphere of density 1g/cm^3 that has the same inertial properties as the actual particle."[1]

Before exploring the three subcategories, a sense of context and scale is helpful. One human hair is generally 50–70 µm, while a fine grain of beach sand is about 90 µm.

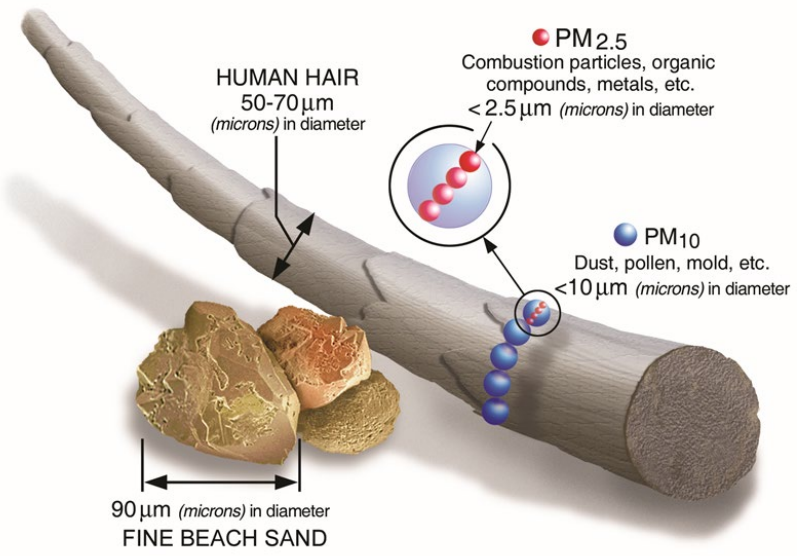


Figure 1Image credit: Environmental Protection Agency

[1] https://www.sciencedirect.com/topics/engineering/aerodynamic-diameter

Coarse particles are physically the largest particles at 2.5 µm to 10 µm.

Common examples include the following:

- Bacteria
- Dust
- Fly ash
- Mold spores
- Pollen
- Smoke

Fine particles are those ranging from 0.1 µm to 2.5 µm. This is, arguably, the most studied type of particulate matter because of its ability to penetrate deep into lung tissue or even to enter the bloodstream. (See "Personal Health Effects" for more information on the health hazards of $PM_{2.5}$.)

Common examples include the following:

- Tobacco smoke
- Vehicle exhaust (car, truck, bus, construction equipment)
- Wildfire smoke
- Power plant emissions
- Combustion activities

Airborne viruses can also fall into this category or the ultrafine category. The diameter of a SARS-CoV-2 particle, for example, ranges from 0.05 µm to 0.14 µm.[2]

Ultrafine particles are those 0.1 µm or less. This group largely originates by nucleation process from the same sources that generate $PM_{2.5}$. With its even smaller size, this group of particulates is able to penetrate deeper into the human body.

Generally speaking, particles created through processes like combustion tend to be fine or ultrafine; particles with a biological origin tend to be coarse.

Common Sources of Particulate Matter

Particulate matter is again divided into two subgroups: primary particles and secondary particles.

Primary particles are emitted directly from sources. This includes any of the following:

- Construction sites
- Fires (manmade or natural)
- Smokestacks
- Unpaved roads
- Vehicle exhaust

[2] https://www.news-medical.net/health/The-Size-of-SARS-CoV-2-Compared-to-Other-Things.aspx

Secondary particles are formed through complex atmospheric reactions of chemicals (or gaseous pollutants) present in particles and gaseous phase in the atmosphere. For example, secondary particles are created by the reaction of emissions from power plants, vehicles, and industrial buildings. They often occur as the result of combustion, and within indoor settings, they can be produced by vacuuming, dusting, cleaning (household cleaning agents) or even cooking.

Secondary particles can form from numerous gaseous pollutants:

- Ammonia
- Nitrogen oxides
- Sulfur dioxide
- Ozone
- Volatile organic compounds (VOCs)

Particulate Matter Is Everywhere

Particulate matter is not an indoor or outdoor issue. It can be found in either setting. It can be present in obvious situations, such as hazy or smoky air, but it can also exist in air that looks, smells, and seems entirely pure and clean. Because of its size, particulate matter can also infiltrate inside buildings. If air quality is low outside, that can affect the levels of particulate matter indoors as well.

This is not a season-specific concern either. Particulate matter populates the air year round. There are, however, seasonal patterns. In the eastern United States, expect particulate matter to be higher in the summertime. On the west coast, particulate matter tends to spike from October through December, when nitrates are more easily formed in the cold weather and smoke from fireplaces and wood stoves contribute to particulate pollution.[3]

As one study led by the University of Washington reveals, the creation and reduction of particulate matter is a complicated, interconnected system that depends on many factors: air quality regulations, the chemistry of wintertime air, amount of sunlight, and temperature.[4]

Complicating the issue, particulate matter can stay suspended in the atmosphere for days or even weeks. Particulate emission from a particular source, whether that be a volcanic eruption or the operation of a power plant, can travel thousands of miles. This means air quality can be affected and impacted in a significant radius around a source of pollution.

Expect particulate matter to be high in any of the following instances:

- Near busy roads with lots of vehicle activity
- In urban areas
- In industrial areas
- Anywhere there's smoke (from wood stoves, wildfires, or campfires)
- When weather is calm and particulate matter can accumulate

[3] https://www.epa.gov/pmcourse/what-particle-pollution
[4] https://www.washington.edu/news/2018/07/23/study-shows-why-eastern-u-s-air-pollution-levels-are-more-stagnant-in-winter/

To give some sense of just how much particulate matter occupies any given space, here are some statistics about particulate matter generation:

- Sitting generates approximately 100,000 particles per cubic foot.
- Standing up generates approximately 2,500,000 particles per cubic foot.
- Walking generates approximately 10,000,000 particles per cubic foot.

Is Particulate Matter Harmful?

There is a direct link between particle size and any corresponding health concerns.[5] Anything larger than 10 micrometers is less of a health concern. These particles, however, can irritate airways, noses, eyes, and throats. The smaller the particle becomes, however, the deeper it lodges into your lungs or even your bloodstream.

- 5–10 µm: Enters nose and pharynx
- 3–5 µm: Enters trachea
- 2–3 µm: Enters bronchia
- 1–2 µm: Enters bronchioles
- 0.1–1 µm: Enters alveoli

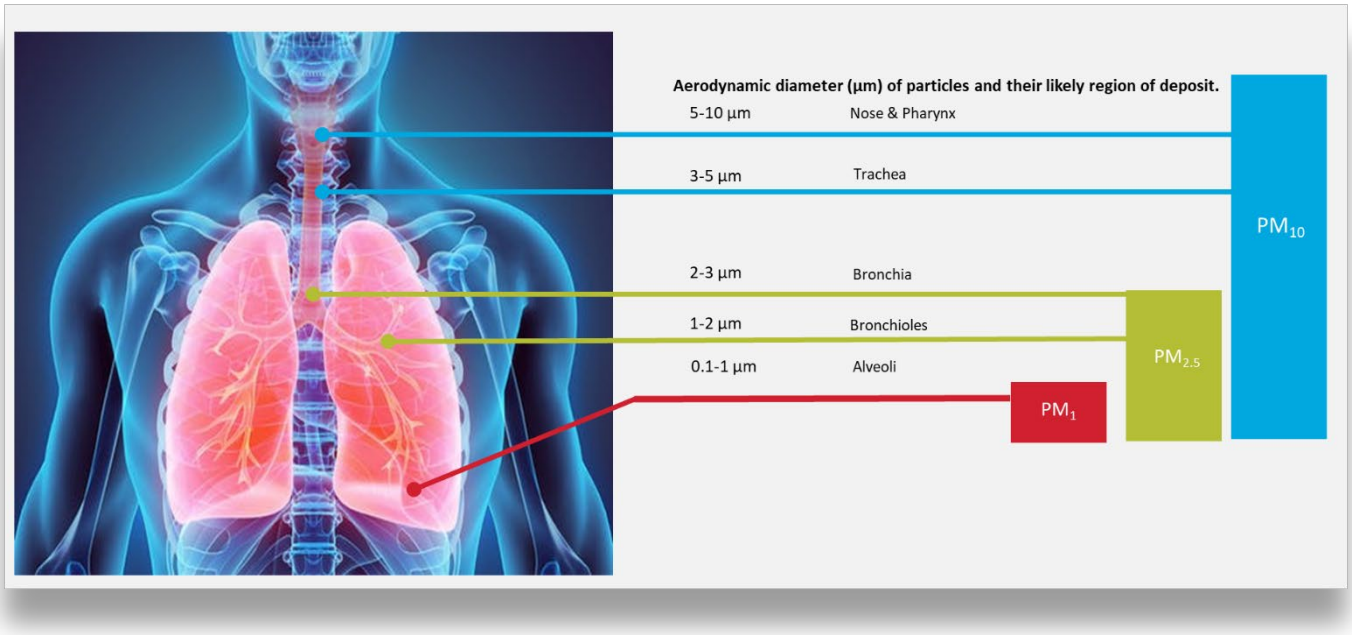


Figure 2 The finer the particulate matter the deeper it enters the respiratory system.

[5] https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm

Personal Health Effects

Exposure to particulate matter affects both the heart and lungs. It can play a role in any of the following:

- Premature death (for people with preexisting heart or lung disease)
- Heart attack
- Irregular heartbeat
- Worsening asthma or other respiratory symptoms, including airway irritation, coughing, or difficulty breathing
- Decreased lung function

Exposure to particle pollution will not necessarily or immediately cause these symptoms, but there are groups that are more sensitive to the effects of particulate matter. Extra caution should be taken if you fall into any of these categories:

- People with heart or lung issues or disease, including asthma or chronic obstructive pulmonary disease (COPD)
- Children
- Older adults

The other factor to take into consideration is exposure time. Long-term exposure to particulate matter is more likely to cause decreased lung function or issues, such as chronic bronchitis. Short-term exposure, on the other hand, can aggravate asthma, trigger acute bronchitis, cause arrhythmias, or make one more susceptible to respiratory infections.

If you suspect air quality is low and you're sensitive or at-risk for particulate matter, consult the EPA's Air Quality Index (AQI).[6] If particulate pollution is high, be especially sure to limit physical activity outdoors. Exercise causes you to breathe faster and deeper, which can exacerbate the effects of high levels of particulate matter.[7]

Environmental Health Effects

Particulate matter can also have adverse effects on the environment itself. High levels of particulate matter contribute to all the following:

- Reduced visibility (haze)
- Increased acidity of lakes, streams, and other bodies of water
- Altered nutrient balance in coastal waters
- Depletion of soil nutrients
- Damaged farm crops or sensitive forests
- Negatively affected ecosystem diversity
- Increased effects of acid rain

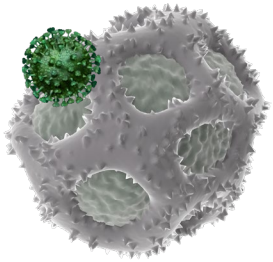
[6] https://www.airnow.gov/
[7] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1001EX6.txt

- Staining or degradation of culturally significant buildings and objects made from stone or other material

The Relationship between Particulate Matter and Airborne Viruses

According to a paper published in *Frontiers in Immunology*, "A number of studies have shown that PM is a carrier of airborne pathogens. For instance, a metagenomic study has confirmed the presence of bacteria, archaea, fungi and dsDNA viruses on PM pollutants collected during a severe smog event in Beijing."[8]

This indicates particulate matter can be a means of transmission for airborne viruses.



Research also indicates a direct connection between the amount of particulate pollution in an environment and the transmission rates and case severity of SARS-CoV-2 specifically: "A number of recent studies have suggested some correlations between air pollution and coronavirus disease-2019 (COVID-19) cases and deaths. For instance, a recent epidemiological study concluded that an increase of 1 μg/m3 in long-term exposure to fine PM air pollutants (≤2.5 μm, PM2.5) is associated with an 8% increase in COVID-19 mortality rate in the United States."[9]

Why Mitigate Particulate Matter?

Given the prevalence and negative health effects of particulate matter, it's important for commercial and residential spaces to know how to reduce PM.

For private homeowners, this is critical for anyone with the underlying health or age-related concerns that make particulate pollution a more serious health issue.

In the commercial sector, this is equally important. A wide range of people come to a business, any of whom might have these underlying conditions. In a pandemic-influenced world, reducing particulate matter increases the overall safety of the environment. This can boost patron confidence, as well as revenue potential.

Reducing Particulate Matter with Indoor Air Quality Improvement Technologies

One way of reducing PM in an environment is with indoor air quality technologies such as electronic air filtration devices.

To test the efficacy of one such technology, a global hospitality provider conducted pilot programs installing needlepoint bipolar ionization devices in four of its North Carolina locations.

- **Technology Used:** Needlepoint bipolar ionization units paired with a MERV-8 filter.

[8]https://www.frontiersin.org/articles/10.3389/fimmu.2020.579352/full#:~:text=A%20number%20of%20studies%20have,event%20in%20Beijing%20(8).
[9] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7543093/

- **Test Intent:** To document the efficacy of a MERV-8 filter and needlepoint bipolar ionization technology together and to compare this to the efficacy of expensive standalone MERV-13 filter.
- **Test Duration:** Technology was installed June 19, 2021 and post-install air quality results were gathered June 25.
- **Data Gathered:** The test analyzed captured particulate matter (0.3 microns to 10 microns) and compared the results between the independent MERV-13 filter and the coupled needlepoint bipolar ionization and MERV-8 filter.
- **Test Results:** Using aggregate data across multiple sites, the MERV-8 filter with the needlepoint bipolar ionization technology operated at 70 percent efficiency. This equaled or outperformed the independent MERV-13 filter.

This test verified that the default HVAC filter (MERV-8) acted as effectively as a MERV-13 filter when used in conjunction with needlepoint bipolar ionization.

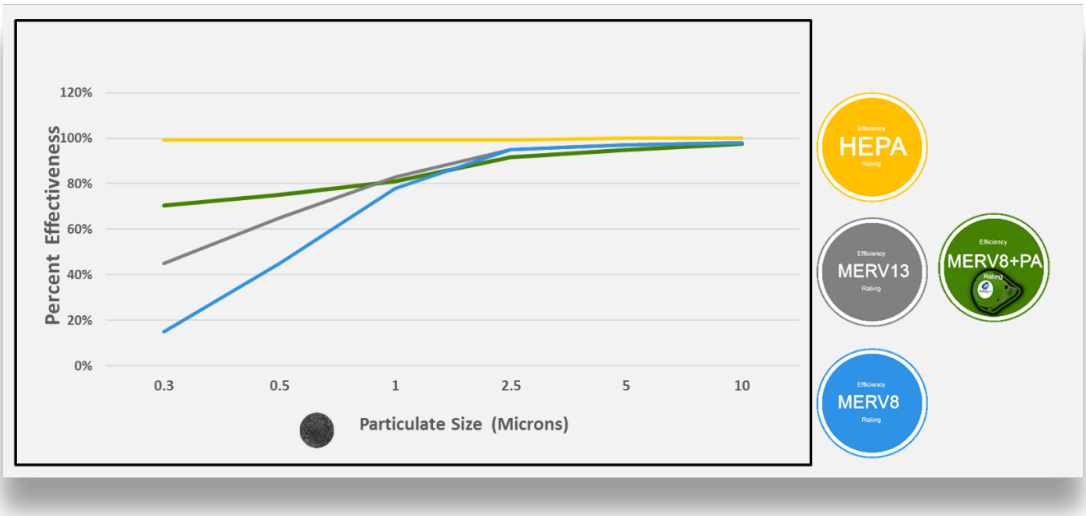


Figure 3 Findings of Global Hospitality pilot project performance of needlepoint bipolar ionization technology.

Related to virus mitigation strategies and air filtration, the Environmental Protection Agency (EPA) underscores the need to make HVAC filtration just one part of any COVID-19 or virus mitigation plan. These actions should be still be coupled with all pandemic-related best practices, including frequent hand washing, mask wearing, social distancing, and vaccination.[10]

ASHRAE also emphasizes there is more nuance to filter efficacy than simply putting one in an HVAC system.[11] This includes the following:

- The need to run the HVAC system to provide constant supply air
- The best practice of sealing a filter in place (rather than sliding it into place)
- The need to change filters periodically
- The understanding of what a MERV filter can and cannot capture.

[10] https://www.epa.gov/coronavirus/what-kind-filter-should-i-use-my-home-hvac-system-help-protect-my-family-covid-19

[11] https://www.ashrae.org/news/ashraejournal/debunking-myths-about-merv-air-filtration

Conclusions and Key Takeaways

- Particulate matter is everywhere.
- Particulate matter ranges from dust and pollen to smoke and bacteria.
- The smaller the particulate matter, the more deeply it can lodge within the lungs and the more related health concerns there are.
- Particulate matter can serve as a transport mechanism for airborne viruses, including SARS-CoV-2.
- When used and installed properly, indoor air quality improvement technologies, including needlepoint bipolar ionization, can help reduce the amount of particulate matter in an environment.