MARYLAND
Department of the Environment

Seasonal Report

2014 Fine Particles ($PM_{2.5}$)

OVERVIEW – CLEANEST EVER

Fine particle pollution (also called $PM_{2.5}$) is a concern throughout the year in Maryland since it is not dependent on sunlight and warmth like ozone, allowing it to impact Maryland's air quality in any season. Due to the very small size of $PM_{2.5}$ pollution, it can penetrate deep into the lungs resulting in breathing and heart health concerns if airborne concentrations are too high. Over the past decade the number of days with high $PM_{2.5}$ concentrations has substantially decreased due to the adoption of emission controls. When $PM_{2.5}$ concentrations are great enough for health concerns in sensitive populations, the Air Quality Index (AQI) exceeds 100. The annual severity of $PM_{2.5}$ is measured by the number of days the daily 24-hour average concentration of $PM_{2.5}$ (midnight to midnight) exceeds the AQI value of 100 in a given year[1]. Currently no short-term (i.e. hourly) National Ambient Air Quality [Health] Standard (NAAQS) exists. In 2014, there were ZERO days which exceeded the Environmental Protection Agency's health based threshold, making it the cleanest year on record for Maryland particle pollution.

WHAT ARE FINE PARTICLES ($PM_{2.5}$)?

Unlike ozone, which is a gas, $PM_{2.5}$ is a solid particle of pollution suspended in the air. Because of its very small size, very small air movements are able to keep it suspended in air. These particles are smaller than the diameter of a human hair *(Figure 1)* and less than 2.5 microns across (1 micron is 0.000001 meters) giving these "Fine Particles" their secondary name: "$PM_{2.5}$". At this size, pieces of pollution are actually able to pass through the lungs into the blood stream! Because of the dramatic health effects high concentrations of $PM_{2.5}$ can cause, $PM_{2.5}$ is an important pollutant to monitor and track.

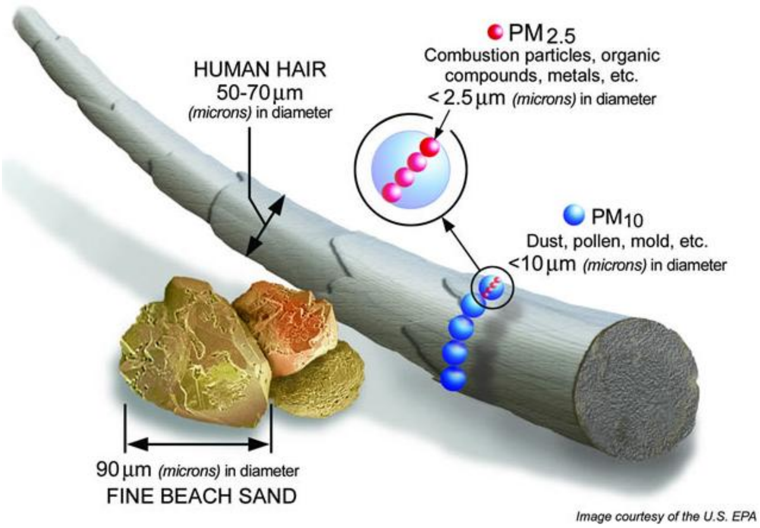

Figure 1: A relative size comparison of the human hair, fine beach sand, and course particle pollution (2.5 - 10 microns in diameter) to fine particles ($PM_{2.5}$).

$PM_{2.5}$ can originate from many different sources including diesel exhaust, fires and combustion *(Figure 2)*, power plant emissions, and can even be created by reactions between different types of pollution, water vapor and sunlight. Weather plays a pivotal role determining the concentration of $PM_{2.5}$ in the air, both directly and indirectly. Abundant moisture in the air aids in the formation of $PM_{2.5}$. The warmer air of summer typically holds more moisture making it directly more conducive for $PM_{2.5}$. Indirectly, electrical production on power plants is higher during summer heat, resulting in higher direct emissions of $PM_{2.5}$ and $PM_{2.5}$ precursors on warm, muggy days. Very cold weather also plays a part by producing strong inversions that trap particle pollution near the surface increasing concentrations substantially, particularly in the pre-sunrise hours.

HOW DO WE OBSERVE AND MEASURE FINE PARTICLES?

$PM_{2.5}$ is customarily measured by trapping fine particle pollution on filters *(Figure 2)*. Outside air is drawn through a filtering medium, leaving the $PM_{2.5}$ behind. Some filters are sent away to special labs to assess the kind of fine particles trapped on them (i.e, wood smoke, diesel exhaust, sulfur). These results are available after a few months or so. Other filtering techniques are much quicker. For example, Maryland has 8 monitors that give hourly readings. Ambient air drawn from the outside via a circular tube first passes through a coarse filter to remove all particles bigger than 2.5 microns, leaving only $PM_{2.5}$ in the air sampled. This sampled air is then drawn through a special spool of paper that captures the remaining particles. After an hour, electrons in a "beta ray" are shot through the dirtied filter paper towards a sensitive detector. Since a dirtier filter "circle" *(see Figure 2)* will block more electrons, we can interpret $PM_{2.5}$ concentrations by the number of fewer electrons reaching the detector. There are 24 hourly readings taken every day at each of the 8 MDE hourly $PM_{2.5}$ monitors, making up the 24 hour average at each of these sites, which determines the daily AQI value for $PM_{2.5}$.

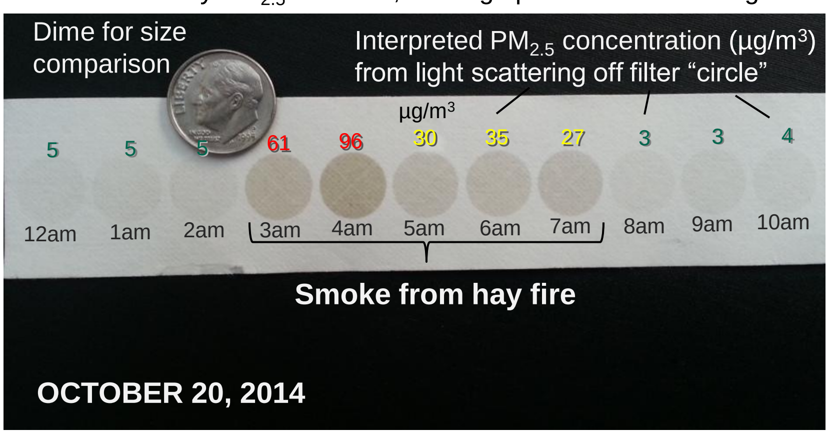

Figure 2: The filter paper or "tape" as called by MDE field technicians from October 20, 2014 is displayed along with a dime for size comparison. The circles on the center of the white strip of filter paper represent hourly collections of fine particle ($PM_{2.5}$) pollution at the Fair Hill monitor in Cecil county Maryland. Hourly concentrations observed at the $PM_{2.5}$ monitor (numbers above the circles) are color coded based on the 24-hour average AQI color set by the EPA; no short-term equivalent AQI exists. Each "circle" is created over an hour as a pump forces air through the paper via a circular tube. Particles of 2.5 microns or smaller are collected on the paper causing a discoloration dependent on the amount and type of pollution.

*The instrument then shoots a stream of electrons, a "**beta ray**", through the filter "tape" at a detector that counts the number of electrons hitting it. The difference in the number of electrons passing through a clean and the dirtied filter is converted to an average $PM_{2.5}$ concentration over the past hour, giving the "**mass** of $PM_{2.5}$ in a volume of **air**" or simply "µg/m³." Approximately 5 hours of smoke from the nearby hay barn fire were detected by the Fair Hill monitor before the wind shifted again and blew smoke away from the instrument.*

AQI 0-50	51-100	101-150	151-200	201-300	301-500
Good	Moderate	USG*	Unhealthy	Very Unhealthy	Hazardous

[1] Report based on the revised PM2.5 AQI implemented in 2013.
*Unhealthy for Sensitive Groups

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MDE

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2014 Fine Particles ($PM_{2.5}$)

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HAY FIRE: October 19-21, 2014

$PM_{2.5}$ is found in smoke given off by fires. During mid October of 2014, two large barns full of hay bales caught fire and smoldered for several days. MDE's Fair Hill monitor was just over one mile southwest from the barns *(Figure 3)*. Initially no smoke was detected by the monitor. Instead, clean ambient air was measured as indicated by the green numbers (5 µg/m³) from 12 to 2am on Figure 2. Winds were initially steady out of the northwest. However, between 1 and 4am on Sunday, October 20, the wind changed to out of the east and northeast blowing smoke towards the MDE monitor. During that time period, the Fair Hill monitor saw fine particle concentrations up to 96µg/m³ between 4 and 5am as the wind recirculated back from the south. Eventually this blew the smoke away from the monitor after 7am *(Figure 2)*. The equivalent hourly AQI at 4am was 172, a level considered "Unhealthy" for all if sustained for 24 hours *(see AQI color bar at bottom)*. As the wind continued from the south, fine particle concentrations again dropped to "Good" levels (3 and 4 µg/m³ at 8, 9, & 10am).

Figure 3: The location of the Fair Hill monitor in relation to the hay fire referenced in the text., with a wide-scale inset map to help identify the location in Maryland. The Fair Hill monitor is southwest of the fire, meaning that northeasterly winds are needed to blow smoke from the fire towards the monitor to detect greater fine particle concentrations.

The "tape" or spool of circular filters used to measure fine particle concentrations on an hourly basis (see Figure 2) at Fair Hill observed higher morning concentrations the day following that shown in Figure 2 day as well (not shown). This was due to the nocturnal inversion that develops between sunset and sunrise and causes pollution to concentrate near the surface. The hay fire provided an opportunity to observe this weather phenomenon. As the inversion broke after sunrise on October 21st the smoke dispersed and $PM_{2.5}$ concentrations again decreased.

TRENDS IN FINE PARTICLE AIR QUALITY

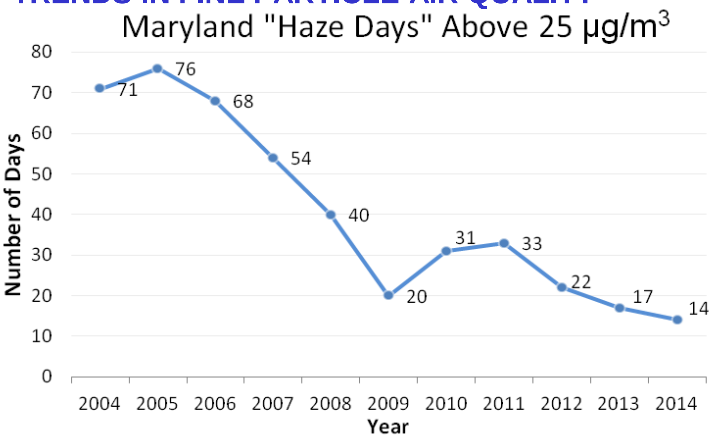

Figure 4: A line graph of the number of "haze days", or days when the 24-hour average concentration of fine particles ($PM_{2.5}$) at any one Maryland monitor is greater than 25 µg/m³ (78 AQI). The number of days above 25 µg/m³ has dropped over 80% since 2004.

Thankfully, the general public does not need fancy equipment to assess air quality. Just like the effects on light reflecting off the circular area on the filter paper is used in MDE's equipment, $PM_{2.5}$ affects light in the atmosphere, causing "haze" to appear to the human eye. Haze is therefore a good (albeit subjective) measure of air quality. There are some major caveats, since haze can also be caused by ozone and an overabundance of moisture in the air, but $PM_{2.5}$ is most certainly also associated with haze.

Experience shows that days with $PM_{2.5}$ concentrations greater than 25µg/m³ (78 AQI) are perceptibly hazy. Since the number of days Maryland exceeds the $PM_{2.5}$ NAAQS (24-hour average greater than 35.5µg/m³) has bottomed out the last few years, the haze threshold provides an alternative measure of $PM_{2.5}$ trends. Over the past 10 years the number of PM "haze days", days with a 24-hour average concentration greater than 25µg/m³ (78 AQI), has dropped by over 80% *(left, Figure 3)*!

HAZE EXPLAINED

What causes the haze when particle concentrations become significant? Sunlight on a clear, clean day passes through an atmosphere containing very small molecules of mostly nitrogen and oxygen, what we call "air". When particle concentrations in the air increase, that same sunlight must pass by objects bigger than the nitrogen and oxygen in the air. This causes the sunlight to deflect in all directions and creates several distortions which humans perceive. First, distant objects are not nearly as "sharp" or clear as on a clean day. Like looking through ripples on water, the particles cause shapes to lose their definition. Second, objects lose their coloring and take on a milky brown appearance. Since the particles in the air deflect all colors of the rainbow but not equally, the colors mix together to make the nasty haze color once the light reaches our eye *(Figure 5)*. In clean air, these effects are negligible.

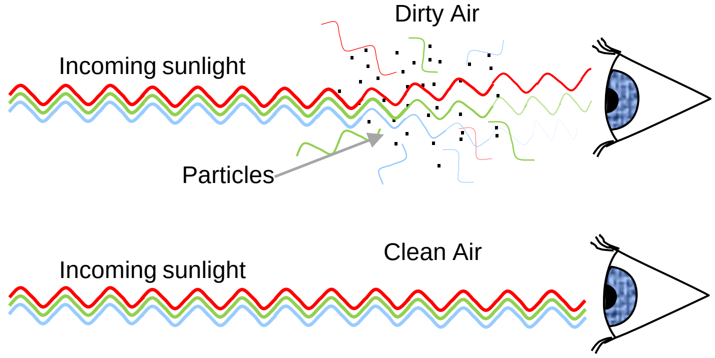

Figure 5: A schematic of how particles in the air cause changes in the light hitting our eye, creating the effect we know as "haze". In air dirty with particles, light is deflected off of its course, with some colors deflected more than others. As a result, the light beam reaching our eye has a different hue (usually a white/brown) and is often unfocused or less sharp than it otherwise would be (as illustrated by the waveforms spreading out). Notice in the clean air, the incoming sunlight reaches the eye unaffected, resulting in a sharp, colorful image.

AQI 0-50 Good	51-100 Moderate	101-150 USG*	151-200 Unhealthy	201-300 Very Unhealthy	301-500 Hazardous