Seasonal Report

2015 Fine Particles ($PM_{2.5}$)

Maryland Department of the Environment

OVERVIEW

Similar to recent years, 2015 was once again another very clean year for fine particle ($PM_{2.5}$) pollution. The Environmental Protection Agency (EPA) sets the National Ambient Air Quality [Health] Standards (NAAQS) for six pollutants, one of which is $PM_{2.5}$. When the midnight to midnight daily 24-hour average $PM_{2.5}$ concentration exceeds 100 on the Air Quality Index (AQI) (*see bottom page),* it is deemed an exceedance day or unhealthy for sensitive groups (USG). Exposure to high concentrations of $PM_{2.5}$ can cause adverse health effects. Due to its small size (*<2.5µm in diameter*), $PM_{2.5}$ can penetrate deep into the lungs resulting in adverse breathing and heart health effects. Over the past decade the number of days when $PM_{2.5}$ concentrations have reached or exceeded USG has substantially decreased primarily due to the adoption of regulations to reduce emissions of SO_2 and NO_x *(Figure 1).* 2015 had ZERO days where the AQI exceeded the USG threshold of 100.

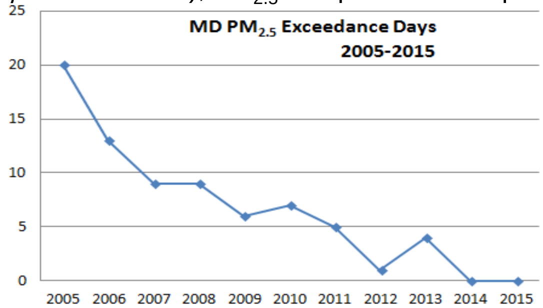

Figure 1: Number of days where the AQI reached 100 or greater at any $PM_{2.5}$ monitor in Maryland annually, 2005-2015.

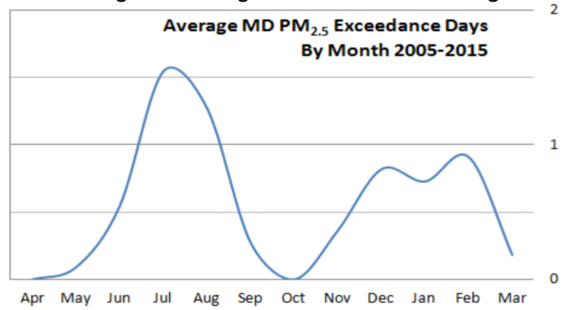

Figure 2: Average number of days where the AQI reached 100 or greater at any $PM_{2.5}$ monitor in Maryland monthly, 2005-2015.

WEATHER AND FINE PARTICLES

Weather plays a vital role in the fine particle concentrations that are observed at the surface, both directly and indirectly. Sources of $PM_{2.5}$ and precursors come from combustion activities such as motor vehicles, wood burning stoves and power plants. Extremes in temperature, both hot and cold, result in the need for more electricity. Power plants work overtime in providing us the necessary electricity, but in turn produce more $PM_{2.5}$ as well as $PM_{2.5}$ precursor gasses. Warm temperatures also have a secondary influence on $PM_{2.5}$ concentrations. With warmer temperatures comes more direct sunlight as well as the ability to hold more moisture in the air. Both of these conditions are favorable for higher $PM_{2.5}$ concentrations which is what leads to a spike in $PM_{2.5}$ exceedance days during hot and humid summer months (*Figure 2*).

The cold winter months also cause a spike in power plant emissions due to increased demand. However, when compared to summer, the length of daylight is shorter and the air is much drier. So what causes this secondary spike in $PM_{2.5}$ concentrations? The answer lies in the weather patterns associated with the winter months. Commonly, high pressure systems work their way down from Canada and remain stationed over our area for several days. This causes light winds and temperatures at the surface to remain cold. Although the temperatures at the surface are cold, the temperatures on some occasions only a few hundred feet above the surface are a bit warmer. This vertical temperature profile is known meteorologically as an inversion. As shown in *Figure 3,* an inversion acts as a lid and keeps pollutants being created trapped near the immediate surface. Inversions are strongest during the overnight and early morning hours, when surface temperatures are usually coldest. Normally, inversions dissipate as the sun begins to warm the surface. However, if the weather pattern persists and the inversion stays strong, it can lead to USG or higher AQI's. This common winter meteorological setup is what leads to the secondary spike in $PM_{2.5}$ exceedances seen in *Figure 2*.

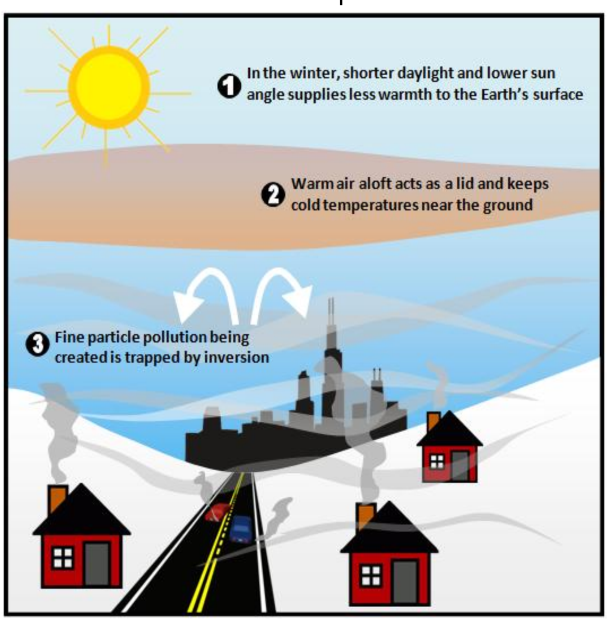

Figure 3: Visual representation of a temperature inversion, common in the winter months which is linked to high $PM_{2.5}$ concentrations.

Additionally from *Figure 2,* it is worth noting that there are very few $PM_{2.5}$ exceedances in spring and fall. Once again if we look at normal temperatures during these times frames, they are "comfortable". There is less need for heat and/or air conditioning. This puts less strain on power plants and can reduce emissions. Additionally, both the spring and fall are known as transitionary seasons from summer to winter (fall) or winter to summer (spring). This creates a lot of variability in our weather. Large temperature swings from one day to the next are common, as well as sunny one day and heavy rain the next. In order for $PM_{2.5}$ concentrations to rise, there needs to be a general stagnation of the air for an extended period of time. Due to the variability in these months this is generally not the case, keeping $PM_{2.5}$ exceedances to a minimum.

2015 FINE PARTICLES AIR QUALITY

2015 had a relatively even number of days of Moderate and Good air quality, 55.6% versus 44.4%, respectably. *Figure 4* (*on page 2*) shows the monthly distribution of Good versus Moderate AQI days throughout the months of the year. The month with the most number of Good AQI days matched up well with typical climatology (October). November, April and June were next highest with each having 17 days of Good AQI. November and April match up with expected climatology; however June was a bit of an anomaly. June being a

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

*Unhealthy for Sensitive Groups

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2015 FINE PARTICLES AIR QUALITY (*cont.*)

summer month typically has higher concentrations of fine particles. The explanation behind this has to do with the abundance of precipitation Maryland experienced during the month of June. BWI reported 13.09'' of precipitation. This is nearly four times the normal average of 3.46''! More precipitation is due to more storm systems and more fronts which aid in keeping the air cleaner than is typically expected during the hot and humid month of June.

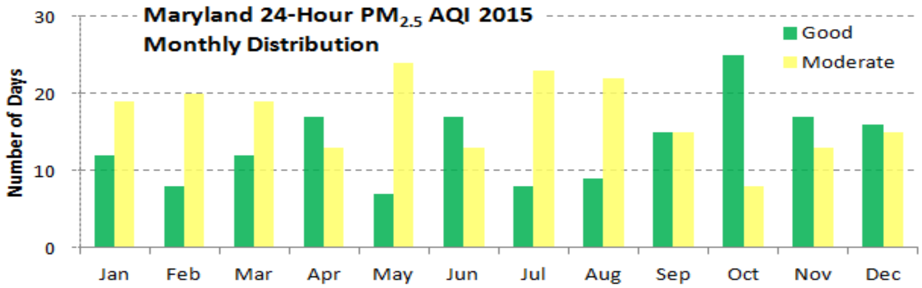

Figure 4: Maryland's monthly $PM_{2.5}$ AQI category distribution for each month of 2015. Columns are color coded by appropriate AQI.

FEATURED EPISODE: December 11-13, 2015

A long duration, stagnant pattern persisted during the timeframe of December 6th through December 13th, peaking between December 11th through December 13th. This pattern was characterized by high pressure, weak winds and a strong surface inversion especially during the overnight and early morning hours. All of these conditions are favorable for high $PM_{2.5}$ concentrations.

Elevated $PM_{2.5}$ concentrations began on December 6th as a high pressure system set up to our south. A very weak southwesterly flow persisted between December 6th through December 10th, gradually increasing our temperatures as well as dew points. $PM_{2.5}$ concentrations during this time frame were elevated, but still well below USG. During the morning hours of December 11th, a weak frontal boundary began to work its way from the north and eventually became stalled over the state by the morning hours of December 12th. The unique topography of Maryland allowed for the frontal boundary to kink southward just east of the Appalachian Mountains, allowing relatively cool air to work its way in from the north *(Figure 5)* removing the warm air at the surface. Temperatures aloft however were still quite warm. This set up a very strong temperature inversion at locations just north of the stationary boundary. During the morning of December 12th, temperatures at ground level in nearby Sterling, VA were 42.8°F (6°C). When compared to just 900 feet above the surface, the temperature shot up to 64.4°F (18°C). This is an impressive 21.6°F (12°C) increase in temperature in less than 1,000 feet! With an inversion that strong, any pollutants emitted were trapped and focused right at the immediate surface. It is at this point where Maryland sees its highest concentrations of $PM_{2.5}$. As seen in *Figure 6*, several stations recorded hourly $PM_{2.5}$ concentrations well into the USG range with the Oldtown monitor peaking at just over 50 µg/m³.

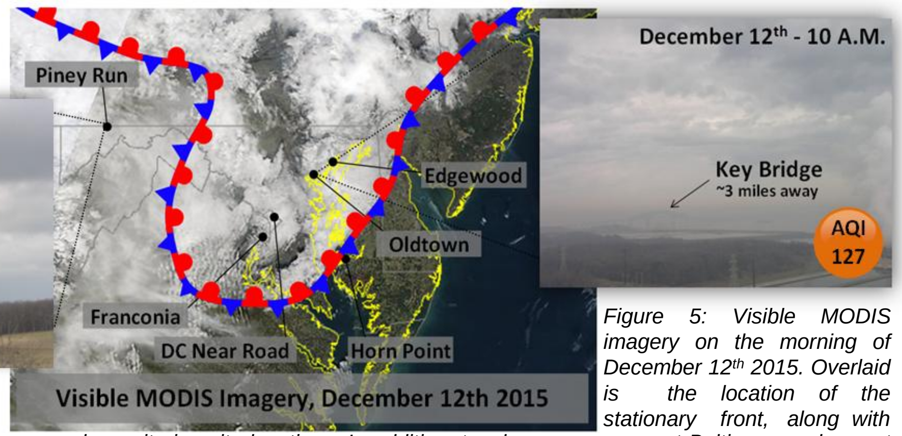

Figure 5: Visible MODIS imagery on the morning of December 12th 2015. Overlaid is the location of the stationary front, along with several monitoring site locations. In addition, two haze cams, one at Baltimore and one at Piney Run at 10 A.M. showing AQI values from nearby monitors.

What is interesting to note is the air quality comparison on one side of the frontal boundary versus the other. On the "cold" side, locations north of the stationary boundary, the air quality was quite poor. However, on the "warm" side, the air quality was much better. Piney Run, a high elevation monitor in western Maryland, remained on the "warm" side for the duration of the event. Locations south of the frontal boundary, such as Piney Run had a very weak surface inversion allowing fine particle concentrations to be much lower. *Figure 6* shows Piney Run in comparison to other monitors that were north of the stationary boundary for most if not all of the event.

As temperatures gradually rose throughout the day, the surface inversion weakened and fine particle concentrations returned to Moderate AQI levels. This pattern persisted on December 13th as well, keeping AQI values quite elevated. Finally on December 14th, a strong cold front swept through clearing out the stagnant air and returning AQI values back to the Good range.

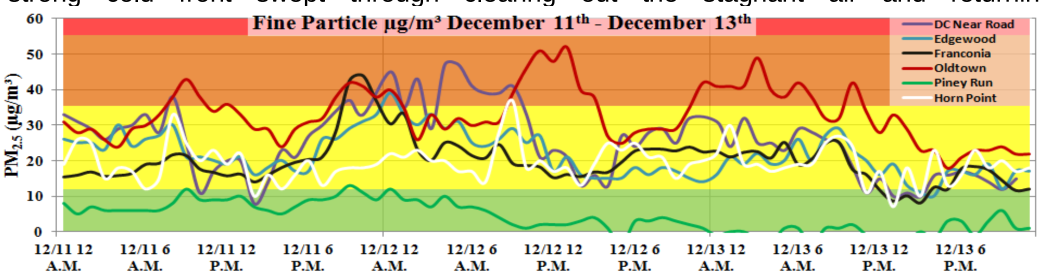

Figure 6: $PM_{2.5}$ concentrations (µg/m³) for several monitors between the timeframe of December 11th – December 13th. Horizontal coloring matches with appropriate AQI ranges.

Despite the supportive atmospheric setup, no monitor recorded an exceedance day during this time frame. Although overnight and morning hourly concentrations were in the USG range for many monitors, the 24-hour average was just under. 24-hour AQI's at the highest monitor (Oldtown) for December 11th through December 13th were 94, 100 and 92, respectively. This lends credence to the success of clean air regulations.

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