Particulate Matter Pollution from Maryland Power Plants

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Table of Contents

Executive Summary

Particulate matter from power plants is a serious health threat. Better monitoring of particulate matter emissions from coal-fired power plants in Maryland and proper enforcement of emission standards would help to reduce health-damaging pollution.

Power plants release particulate matter, or soot—tiny particles that are too small to see and that can be inhaled deep into the lungs, where they cause health problems.

- Particulate matter can suppress immune function, cause cancer and worsen cardiovascular disease and impair children's lung development.
- Very fine particulate matter, known as $PM_{2.5}$, has the greatest health impacts.
- Particulate matter pollution from coal-fired power plants in Maryland causes an estimated 560 premature deaths, 21,000 asthma attacks and 350 pediatric emergency room admissions each year.

Coal-fired power plants release more particulate matter pollution than do other fossil-fuel plants, and a large portion of that pollution is $PM_{2.5}$.

- Oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) are pollutants that can react to form particulate matter. Coal-fired power plants emitted 93% of NO_x and 99% of SO_2 released from electricity generation in Maryland in 2004.
- Approximately 21 to 44% of the particulate matter pollution released from coal-fired power plants is $PM_{2.5}$.
- Particulate matter pollution is dangerously high in 11 of Maryland's 23 counties, including six that are home to the state's major coal-fired power plants.

Despite the health risks of particulate matter, power plants in Maryland currently do not measure their particulate matter emissions. Instead of tracking emissions and requiring power plants to meet the state's standards for particulate matter, power plants are required to monitor for "opacity" of their emissions.

- Maryland's standard for opacity does not guarantee that the state's standard for particulate matter pollution will be met. The opacity standard allows emissions to spike once an hour, allowing power plants to emit more particulate matter than they should be allowed to emit under state regulations.
- Opacity is a poor measure of particulate matter pollution. The U.S. Environmental Protection Agency says that specific particulate matter levels cannot be determined from a given level of opacity.

An additional problem with particulate matter pollution in Maryland is that many coal-fired power plants have not been complying with the already inadequate opacity standard. For example, data from Brandon Shores show that there were at least 62 events from January 2005 through December 2006 in which the plant exceeded opacity limits.

To protect public health from particulate matter pollution, Maryland should require all coal-fired power plants to measure the particulate matter coming out of smokestacks, thus making it possible for the state to fully enforce its standards for particulate matter, rather than relying on

the inadequate and inaccurate opacity standards. Doing so would enable the state to ensure that unsafe levels of particulate pollution are not permitted to harm public health.

Particulate Matter Pollution in Maryland

Health Impacts of Air Pollution

The brownish haze visible on the horizon throughout central Maryland almost seems natural because of its frequent presence. However, this pollution is anything but natural. It comes from burning fossil fuels, and consists of extremely small and practically invisible particles in the air, known as particulate matter or soot.

Some types of soot are simply unburned fuel particles. Forty to 1,000 times smaller than the width of a human hair, these fine particles result from burning coal, gasoline, or diesel fuel. Other types of soot are created when pollutants react with each other in the atmosphere. Particles can contain hundreds of different chemicals, such as cancer-causing agents like polycyclic aromatic hydrocarbons, as well as metals like arsenic and zinc.

Fine particles can remain suspended in the air for weeks. They can travel through building shells and conventional heating and air conditioning filters. When inhaled, they are able to penetrate deep into the lung where they deliver their toxic payload. In contrast, larger particles such as dust or pollen travel shorter distances and are more effectively trapped in the body's upper airway.

Fine particles penetrate to the deepest part of the lung, where they are attacked and absorbed by immune cells. In an experiment in England, ultra fine carbon particles showed up in the immune cells of every child tested—even in a three-month old infant.[1] Some of the particles remain trapped in the lung, while others travel through the blood to the rest of the body.[2]

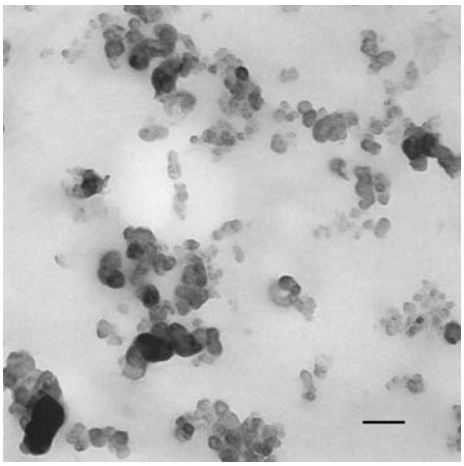
The chemicals delivered into the body by inhaled particulates are very dangerous. Some of them cause cancer, some irritate lung tissues, and some change how the heart functions.[3] Exposure to particulate matter also is suspected to depress immune function, increasing susceptibility to other disease.[4] As a result, particulates cause and aggravate a host of health problems, including lung cancer and cardiovascular disease.

Particulate pollution can cause irreversible damage to children, interfering with the growth and development of the lungs. For example, researchers at the University of Southern California followed the health of more 1,000 ten-year-olds until they reached 18. Children who lived in areas with higher levels of particulate pollution were less able to breathe with normal capacity.[5]

Particulate pollution also can be deadly, killing upwards of 50,000 Americans every year. In fact, according to the largest study of the effects of particulates on mortality, breathing the air in major U.S. cities is about as dangerous as living or working with a smoker.[6] According to another analysis, an additional 10 micrograms of particulate matter per cubic meter of air results in a 0.7% increase in deaths from air pollution. The impact of increased particulate matter concentration is especially noticeable when the particulate matter is smaller than 2.5 micrometers in diameter ($PM_{2.5}$).[7]

Eleven of Maryland's 23 counties fail to meet federal health standards for $PM_{2.5}$.[8]

Photo 1. Soot Particles[9]



Very small soot particles found in diesel exhaust. The scale bar represents 10 nanometers.

Particulate Matter from Power Plants

Power plants are a major source of particulate matter (PM) pollution, the result of both unburned fuel particles and of chemicals that react to form particles. Further, PM pollution from coal plants includes a high proportion of $PM_{2.5}$, the smallest and most damaging size.

Coal Produces More PM Than Other Fuels

Coal-fired electric generating units in Maryland produce higher PM emissions per megawatt-hour than power plants using other fuels. PM emissions are not measured precisely, so no data are available on the exact amount of PM from coal-fired units versus others. Data on other pollutants, however, indicate the disproportionately high share of pollution coming from coal-fired power plants.

Power plants produce oxides of nitrogen (NO_x) and sulfur dioxide (SO_2), compounds that can react to form PM. In fact, SO_2 is the biggest contributor to fine particle pollution from power plants.[10] Table 1 shows that coal plants account for 62% of total generating capacity in Maryland, yet emit 93% of NO_x and 99% of SO_2 released from electricity generation in Maryland. PM emissions from these coal-fired sources represent at least as high a proportion of total PM emissions by electric generators in Maryland.

Table 1. Proportion of Pollution from Coal-Fired Power Plants in Maryland[11]

Plant Name	County	Annual Net Generation (thousand MWh)	NO_x tons	SO_2 tons
Morgantown	Charles	6,629	13,759	81,000
Chalk Point	Prince George's	6,294	14,043	64,647
Brandon Shores	Anne Arundel	8,446	11,893	41,291
Dickerson	Montgomery	3,517	5,828	39,037
C. P. Crane	Baltimore	1,952	7,705	29,043
Herbert A Wagner	Anne Arundel	3,379	6,039	23,288
Luke Mill	Allegany	458	4,185	19,939
R. Paul Smith	Washington	351	753	2,801
Warrior Run Cogeneration Facility	Allegany	1,509	458	1,784
TOTAL OF COAL GENERATING UNITS		**32,534**	**64,663**	**302,830**
TOTAL OF ALL GENERATING UNITS		**52,053**	**69,571**	**304,392**
COAL AS % OF TOTAL		**63%**	**93%**	**99%**

Note that Chalk Point, though listed as a coal-fired power plant, also burns oil, which produces substantial PM emissions.

Coal Produces a High Proportion of $PM_{2.5}$

Exhaust from coal-fired boilers contains both PM and chemicals that can react with each other and other pollutants to form additional PM later. These chemicals are released in gas form and can remain gaseous for distances up to several kilometers from the stack, forming PM at a significant distance downstream from the pollution source.

A large portion of PM from power plants is $PM_{2.5}$. Recent pollution sampling at coal-fired electrical generating units shows that the fraction of PM emitted from the stack as $PM_{2.5}$ equals between 21% and 44%.[12] And according to U.S. Environmental Protection Agency (EPA) data based on estimated emissions, electric utilities were responsible for 27% of statewide $PM_{2.5}$ pollution in 2001.[13]

As mentioned above, eleven of Maryland's 23 counties fail to meet federal $PM_{2.5}$ air quality standards. Five of those counties are home to one or more of the state's six largest coal-fired electrical generators, shown in Table 2.[14]

Table 2. Maryland's Coal-fired Electrical Generating Units and Estimated Filterable PM Emissions[15]

Plant Name	Plant Owner	County	2004 Heat Input (MMBtu)	Does County Meet Federal PM 2.5 Standards?
Brandon Shores	Constellation	Anne Arundel	76,754,347	no
Chalk Point	Mirant	Prince George's	72,313,469	no
Morgantown	Mirant	Charles	62,055,776	no
Herbert A. Wagner	Constellation	Anne Arundel	37,571,547	no
Dickerson	Mirant	Montgomery	34,577,570	no
C.P. Crane	Constellation	Baltimore	21,422,990	no
AES Warrior Run Cogeneration Facility	AES	Allegany	14,815,791	yes
R. Paul Smith	Allegheny Energy Supply	Washington	3,997,496	no
Luke Mill	MeadWestvaco	Allegany	2,897,974	yes

Health Consequences of Particulate Matter from Coal Plants in Maryland

The health impacts of particulate matter pollution from six largest of these coal-fired power plants are significant for both Maryland residents and citizens of neighboring states. A study by Professor Jonathan Levy of the Harvard School of Public Health found that PM pollution from Maryland's six largest coal-fired generators causes 560 premature deaths, 21,000 asthma attacks and 360 pediatric emergency room admissions each year in Maryland and neighboring states.[16] This estimate relies on 1990 population figures; given the region's larger population today, impacts are likely greater.

For Maryland residents, the study estimates that particulate matter pollution from these six plants causes 100 premature deaths, 4,000 asthma attacks, and 80 pediatric emergency room admissions.

The Healthy Air Act, passed in 2006, requires power plants to cut emissions of NO_x by 75 percent and SO_2 by 85 percent, which should reduce particulate matter pollution. However, to ensure the greatest benefit from this legislation, Maryland needs to ensure that power plants are actually reducing their emissions. The current method of monitoring particulate matter emissions does not offer that guarantee.

Standards for Limiting Particulate Matter Are Inadequate

Power plants in Maryland currently do not measure their PM emissions. Instead, they monitor the opacity of emissions as a proxy for PM emissions. There are two problems with this. First, the opacity standard is relatively lax, meaning that power plants that comply with the opacity standard may still be exceeding the PM standard. Second, opacity is an inexact measure of PM concentrations and fails to accurately reveal PM emissions.

Weakness in the Opacity Standard

Air pollution from coal-fired power plants is regulated by both state and federal requirements, as shown in Table 3 (for facilities opened before 1975). The state's standards are more stringent than the federal standards and thus establish plants' legal pollution limits.

The opacity standard requires that emissions from plants not be visible for 54 minutes per hour. Because the Maryland Department of the Environment has determined that a human observer will report an opacity level of between zero and 10% as no emissions, the effective opacity limit is 10%.[17] For one six-minute period per hour, the visible emission limitation of 10% is allowed to rise up to 40% during intermittent events such as startup, load changing, soot blowing or control equipment cleaning.

Table 3. State and Federal Regulations Governing the Release of Particulate Matter from Pre-1975 Coal-fired Boilers[18]

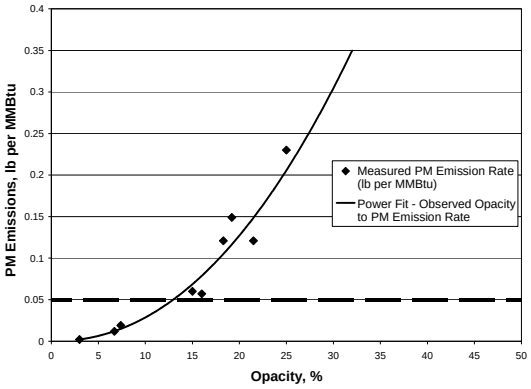
	Federal Regulations	State Regulations
Particulate Matter	40 CFR §60.42(a)(1) limits particulate emissions to 0.10 lb/mmBtu.	COMAR 26.11.09.06B(3) Limits PM to 0.03 grains per standard cubic foot of dry air (compliance to be demonstrated annually). This is approximately equal to 0.052 lb per MMBtu.
Opacity	40 CFR §60.42(a)(2) limits visible emissions to 20% opacity or less.	COMAR 26.11.09.05A(2) No visible emissions, except during load-changing, soot-blowing, start-up or occasional cleaning of control equipment. During these exceptions, visible emissions must not be greater than 40%, and must not occur for more than six consecutive minutes in any 60 minute period.

However, the PM limit does not contain this exception. The PM emission limits apply the entire time the boiler is in operation. Yet, the periodic relaxation of the opacity limits for soot blowing and other activities means that PM emissions also frequently rise.

Data on the relationship between opacity and PM emissions suggest that the periodic increases in allowed in the opacity standard likely result in emissions multiple times above the legal PM emissions limit.

The Electric Power Research Institute (EPRI) conducted tests on opacity rates and PM emissions at a coal-fired boiler with electrostatic precipitator controls, a configuration similar to the Brandon Shores facility in Maryland.[19] The results of that test are shown in Figure 1. EPRI's testing extended only to opacity levels of 25%. The curve fit predicts PM emission rates at opacity levels over 25%.

Figure 1. Observed PM Emission Rate versus Opacity for Pulverized Coal Boiler with ESP Controls from EPRI Study w. Trendline Added



The data presented in Figure 1 suggest that a plant operating in compliance with the opacity standard could still be violating the PM emissions standard. Assume that a plant releases "invisible" emissions that actually are 10 percent opaque for 54 minutes in an hour. Then, for six minutes, the facility releases exhaust that is 40% opaque, causing PM emissions to rise well above the 0.052 lb per MMBtu limit. The exact level of PM emissions is difficult to predict because EPRI included only lower opacity levels in its study. Over the course of a day, if the opacity of emissions reaches 40% for six minutes per hour—correlating, perhaps, to PM emissions of 0.4 lb per MMBtu—the 24-hour average PM emissions could be above the legal limit for PM.[20]

One way of approaching the problem would be to ensure that the 10% opacity limit is met 24 hours per day, thus ensuring that PM emissions never exceed the state standard. Opacity, however, is an imperfect means of measuring PM emissions. The state would be better able to enforce its PM standards and protect public health if power plants were required to monitor their emissions of PM directly.

The Relationship Between Opacity and Particulate Matter

Opacity is widely recognized as a imperfect means for identifying PM emissions. It is positively correlated to increasing PM emissions, but the U.S. EPA states that specific PM emissions cannot be determined from a given level of opacity or from an increase in opacity.[21] In addition, "the particle size distribution and refractive index of the ash particles" make the relationship between opacity and PM concentration highly variable.[22] Thus, opacity is an imperfect criterion by which to judge PM emissions with precision.

If Maryland is to determine with confidence whether PM pollution is at acceptable levels and to readily enforce violations of the PM standard, power plants should directly measure their PM emissions.

Opacity Violations at Brandon Shores

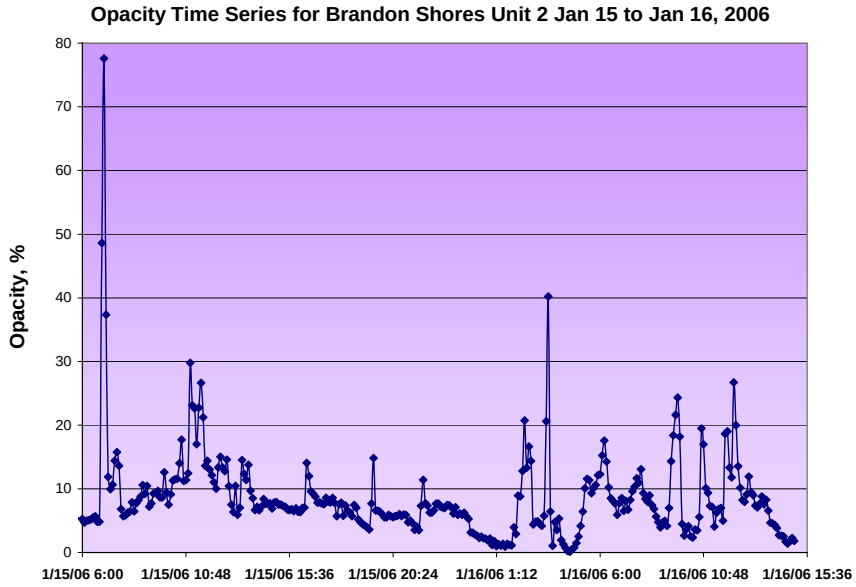
Maryland's opacity standards may already allow power plants to release more hazardous PM than is allowed under the state's PM standard. But some Maryland power plants, such as Brandon Shores, the state's third largest coal-fired power plant, have failed to comply with even the lax opacity standard, suggesting that they have regularly emitted excessive amounts of PM.

A review of emissions data for two boilers at Brandon Shores shows that opacity often reaches levels correlated with high PM rates. In those situations, PM emissions likely exceed the allowable level. Data from January 2005 through December 2006 show that there were at least 62 events during which opacity for Units 1 and 2 exceeded opacity limits. This includes events with consecutive six-minute periods of opacity levels in excess of 10% or when any one opacity level exceeded 40%.

One series of violations occurred on January 15 and 16, 2006. As show in Figure 2, opacity at Brandon Shores' boiler number 2 exceeded the visible emissions limit for extended periods. Opacity remained above 10% for consecutive six-minute intervals, in violation of allowed opacity levels. In the worst period, emissions remained higher than 10 percent for longer than an hour. In addition, the plant also produced emissions well above the 40 percent opacity maximum.

Opacity above 10% is correlated with PM emissions greater than the 0.05 pounds per MMBtu limit. For example, opacity levels of 20% are correlated in Figure 1 with PM emissions of 0.1 to 0.15 pounds per MMBtu.

Figure 2. Excessive Opacity Levels at Brandon Shores



Given the duration of this and other opacity occurrences and their correlation with excessively high PM emission levels, it is likely that the Brandon Shores' emissions not only negatively affect compliance with the 24-hour PM ambient air quality standard at locations close to the plant, but also contribute significantly to the facility's overall annual PM emissions.

Policy Recommendations

To protect public health, power plants in Maryland must reduce their particulate matter emissions. The state also needs to be able to confidently evaluate facilities' compliance with PM emission limits.

Measure Particulate Matter, Not Opacity

Opacity is a weak measure of particulate matter emissions. In addition to the fact that the opacity standard allows an hourly spike in emissions that may cause PM emissions to rise above acceptable limits, opacity measurements fail to reveal precise levels of PM.

To accurately assess—and thus be able to limit—PM pollution from the state's many coal-fired power plants, Maryland should require the installation of continuous emission monitoring (CEM) equipment for PM.

The use of CEMs for PM and other pollutants is already common. Since 2006, federal regulators have required some new power plants—but not existing ones—to install continuous emission monitors for PM.[23] According to one vendor, worldwide applications number in the thousands, with hundreds in use in the U.S., including at two Dominion plants in Virginia.[24] In May 2007, the Maryland Department of the Environment reached a settlement with Constellation Energy about violations of opacity limits at Brandon Shores and two other power plants. As part of that settlement, Constellation agreed to install and operate PM CEMs at Brandon Shores by April 2010.[25]

Maryland's existing power plants already must use continuous emissions monitoring of other pollutants. Under federal acid rain requirements for all plants and New Source Performance Standard requirements that affect plants constructed after 1970, utility generators must show compliance with NO_x and SO_2 emission limits using CEMs. Using methods established by the EPA, these monitors measure and record pollution levels in each plant's smokestack. Pollution measurements are reported to EPA on a quarterly basis and made available to the public.[26] Thus, data are readily available for the agency and the public to ascertain whether the utility is complying with its pollution permits.

Enforce Emission Limits

As mentioned above, the Maryland Department of the Environment (MDE) has recently taken enforcement action against several power plants owned by Constellation Energy for violations of opacity limits. MDE's steps to protect public health should be applauded.

Once continuous emission monitors are in place, the state should shift toward strict enforcement of the numerical limits on PM emissions.

In addition, the state should take prompt enforcement action against power plants when violations occur. The violations cited by MDE in its May 2007 action against Constellation occurred from January 2004 through March 2007.[27] Power plants should not be allowed to spew excessive pollution into Maryland's air for years at a time without enforcement action, thus endangering public health.

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