2025
Delaware Envirothon
Air Quality Student Guide

Checking the Air Because We Care

January 10, 2025
Department of Natural Resources & Environmental Control (DNREC), Division of Air Quality (AQ)
AQ Envirothon Team

Section One: Introduction to Air Pollution

Air is a vital resource that is fundamental for all of our lives – on average, we breathe in and out about 22,000 times each day (Canadian Lung Association, n.d.)! The quality of that air is important for leading healthy lives but can be negatively affected by pollution. Air pollution can be simply defined as gas and particle contaminants present in the atmosphere. Although simple by definition, the potential health and environmental impacts of air pollution have local, state, national and global consequences.

Air Pollutants Overview

While there are many different air pollutants, we'll focus our attention to those that are commonly encountered. The Criteria Air Pollutants (CAPs) are a group of six pollutants that will be discussed throughout this guide and are described in Table 1 (U.S. Environmental Protection Agency [EPA], 2024).

Table 1

Description of the six Criteria Air Pollutants (CAPs)

Carbon Monoxide (CO)	
DESCRIPTION	colorless, odorless gas
SOURCES	greatest sources are cars, trucks, and other vehicles or machinery that burn fossil fuels
HEALTH EFFECTS	reduces amount of oxygen that can be transported in the blood stream to critical organs if inhaled in large amounts
ENVIRONMENTAL EFFECTS	contributes indirectly to climate change because it participates in chemical reactions in the atmosphere that produce ozone
Lead (Pb)	
DESCRIPTION	naturally occurring element found in small amounts in the earth's crust
SOURCES	can be emitted into the environment from industrial sources and contaminated sites such as lead smelters
HEALTH EFFECTS	neurological effects in children; cardiovascular effects, decreased kidney function and reproductive problems in adults
ENVIRONMENTAL EFFECTS	decreased growth and reproductive rates in plants and animals; neurological effects in vertebrates
Nitrogen Dioxide (NO_2)	
DESCRIPTION	one of a group of highly reactive gases known as oxides of nitrogen (NO_x) it is used as the indicator for NO_x
SOURCES	primarily from burning of fuel; forms from emissions from cars, trucks, buses, power plants, and off-road equipment
HEALTH EFFECTS	irritates airways in the human respiratory system
ENVIRONMENTAL EFFECTS	contributes to acid rain which harms sensitive ecosystems, haze, and nutrient pollution in coastal waters
Ground-Level Ozone (ozone)	
DESCRIPTION	found in the lower atmosphere, not emitted directly
SOURCES	created in the lower atmosphere primarily by NO_x and Volatile Organic Compounds (VOCs) reacting in the presence of heat and sunlight
HEALTH EFFECTS	strong respiratory irritant and health hazard, can reduce lung function and harm lung tissue
ENVIRONMENTAL EFFECTS	harms sensitive vegetation during the growing season; reduces photosynthesis; slows plant growth
Particulate Matter (PM) $PM_{2.5}$ - aerodynamic diameter less than 2.5 microns PM_{10} - aerodynamic diameter less than 10 microns	
DESCRIPTION	mixture of solid particles and liquid droplets found in the air, such as dust or smoke
SOURCES	emitted directly from a source such as a smokestack or as a result of a complex reaction of chemicals
HEALTH EFFECTS	increased irritation of the airways, coughing or difficulty breathing $PM_{2.5}$ is a greater health concern because it can get deeper into lungs and into bloodstream
ENVIRONMENTAL EFFECTS	$PM_{2.5}$ – main cause of haze in parts of the United States
Sulfur Dioxide (SO_2)	
DESCRIPTION	is a gas at ambient temperatures with a pungent, irritating odor; is comprised of one atom of sulfur and two atoms of oxygen
SOURCES	larger sources: burning of fossil fuels by power plants, industrial facilities smaller sources: industrial processes, volcanoes, vehicles and heavy equipment that burn high sulfur fuel
HEALTH EFFECTS	harms human respiratory system, making breathing difficult
ENVIRONMENTAL EFFECTS	harms trees and plants by damaging foliage and decreasing growth; contributes to acid rain which harms sensitive ecosystems

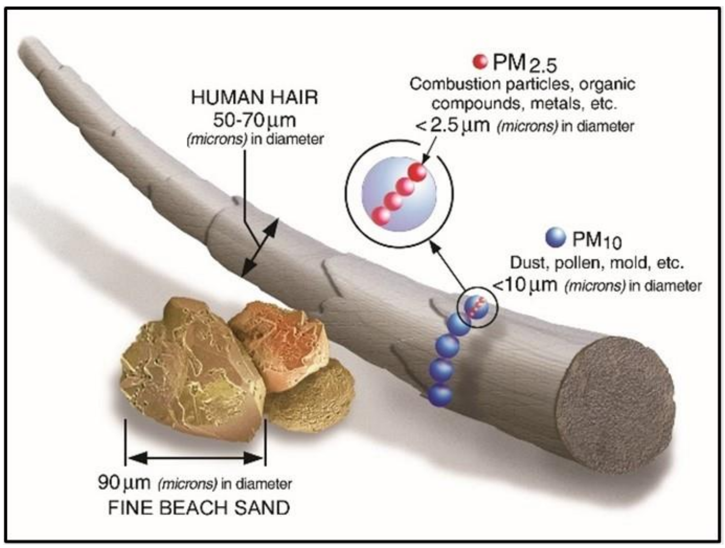
As Table 1 shows, each of the CAPs has unique characteristics and health/environmental effects. The impact of air pollution depends on the pollutant's physical and chemical properties.

For example:

- NO_2 and SO_2 are acidic compounds that can cause damage to the respiratory system when inhaled.
- Similarly, ozone is a powerful oxidant that reacts with and damages living cells, such as those in the lungs (California Air Resources Board [CARB], n.d.-c).
- PM is classified by the diameter of the particle, which is often just a fraction of the size of a human hair as shown in Figure 1. The size and composition of the particle impacts where the particle will travel/deposit and the damage it will cause(CARB, n.d.-a).

Figure 1

Particulate size comparison



Note. From EPA, 2020, Particulate Matter (PM) Basics, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM

As noted in Table 1, NO_2 is part of a group of highly reactive gases commonly referred to as oxides of nitrogen or nitrogen oxides (NO_X). This guide will refer to both NO_2 and NO_X, so be sure to remember that:

- NO_2 is a criteria pollutant, it reacts in the atmosphere to form ozone (aka, an ozone precursor), and belongs to the NO_X family;
- NO_X is a group of seven pollutants (including NO_2) that are collectively considered precursors to ozone formation.

In addition to the CAPs, volatile organic compounds (VOCs) are another group of pollutants mentioned throughout this guide. VOCs are emitted as gases from certain solids or liquids and include a variety of chemicals with short- and long-term adverse health effects. They are emitted by a wide array of products numbering in the thousands and are considered precursor pollutants because they also contribute to the formation of ground-level ozone.

Another group of pollutants are those defined as hazardous air pollutants, or HAPs. HAPs are pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects, birth defects, or adverse environmental effects (EPA, 2024r). Some pollutants classified as VOCs may also be considered HAPs. There are currently 188 pollutants classified as HAPs by the Clean Air Act (CAA).

Air Pollution Sources

Air pollution comes from a variety of sources and each source emits a different variety of air pollutants. For example, highway vehicles release byproducts of combustion (CO, NO_X, SO_2, PM, and VOCs), grain elevators generate emissions of PM, and spray booths emit pollutants that may be considered VOCs and/or HAPs. To keep track of these emissions, the Environmental Protection Agency (EPA) maintains the National Emission Inventory (NEI) – a comprehensive and detailed estimate of air emissions from various emission sources. Air pollution sources are categorized to help create a complete emission inventory into the following groups: point, nonpoint, on-road, non-road, and fire (EPA, 2024k).

Point sources include larger sources that are located at a fixed, stationary location. Point sources include large industrial facilities and electric power plants, airports, and smaller industrial, non-industrial, and commercial facilities.

Nonpoint sources include sources which individually are too small in magnitude to report as point sources. Examples include residential heating, commercial combustion, asphalt paving, and commercial and consumer solvent use.

On-road sources include on-road vehicles that use gasoline, diesel, and other fuels. These sources include light duty and heavy duty vehicle emissions from operation on roads, highway ramps, and during idling.

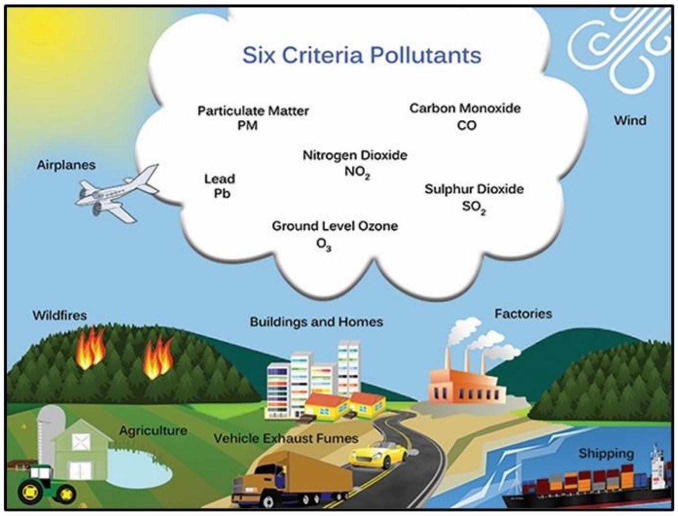
Non-road sources include off-road mobile sources that use gasoline, diesel, and other fuels. Examples include construction equipment, lawn and garden equipment, aircraft ground support equipment, locomotives, and commercial marine vessels.

Fire sources include the major sources of fires: Wild Land Fires (WLF) which is composed of both wild and prescribed fires, and agricultural fires. Taken as a sum, agricultural fires, prescribed fires, and wild fires make up the total emissions that comprise the “National Fire Emissions Inventory” (NFEI).

Figure 2 provides examples of some these emission sources and dispersion methods.

Figure 2

Criteria pollutants and sources

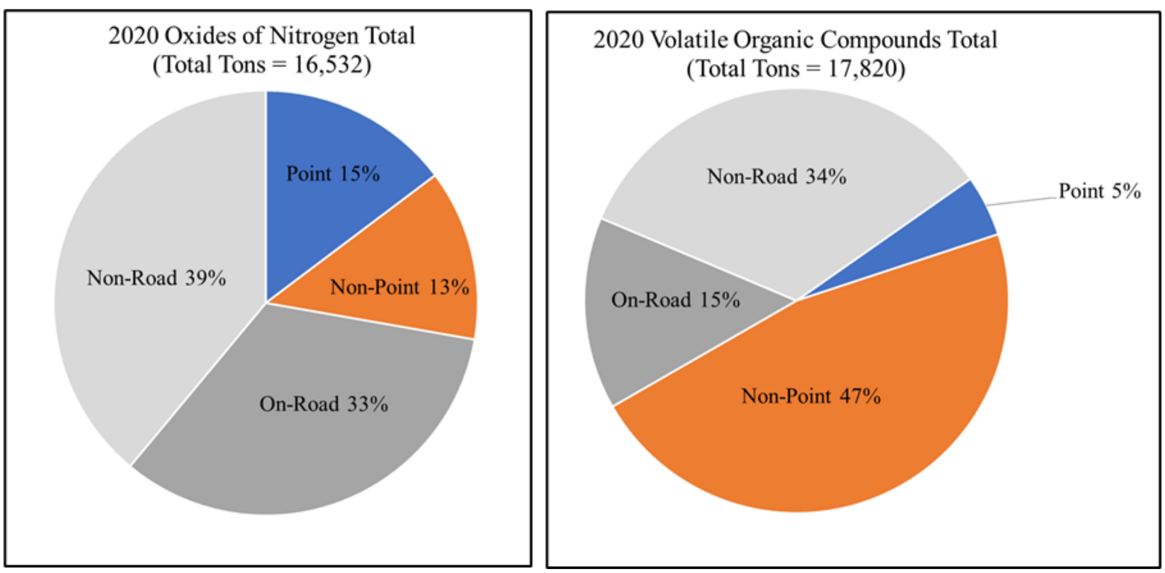


Note. From Irving, J. and Walsh, M., n.d., Shining Light on Pollution, LSU Superfund Research Center, https://gradlsu.gs.lsu.edu/srp/community_resources/shining_light_on_pollution_presentation.pdf

The NEI data can be used to evaluate which source types are contributing the most to air pollution. Looking specifically at ozone precursors, the 2020 NEI indicates mobiles sources are the largest contributors of NO_X (72%) and VOC (49%) emissions in Delaware as shown in Figures 3 and 4.

Figures 3 and 4

Breakdown of source types contributing to ozone precursors – NO_x and VOC – in Delaware



Note. Both figures created by staff using data from 2020 National Emissions Inventory by EPA

Now that we have some background on the common types of pollutants and sources that emit them, let's discuss the laws in place to help protect air quality.

CAA Basics

The CAA is the federal law that defines and controls air pollution in the United States. The CAA regulates air pollution through the development of the National Ambient Air Quality Standards (NAAQS) and the requirement for states to develop corresponding State Implementation Plans (SIPs) to achieve them (EPA, 2024n).

In 1970, Congress passed the CAA authorizing the EPA to establish NAAQS for pollutants shown to threaten human health and welfare. The standards were broken into two categories: primary and secondary. Primary standards were designed to protect public health, including an adequate margin of safety to protect sensitive populations such as children and asthmatics. Secondary standards were designed to protect public welfare including decreased visibility, damage to crops, vegetation, and buildings, etc.

The NAAQS establish health-based standards for each of the CAPs. An air quality standard defines the maximum amount of a pollutant averaged over a specified period of time that can be present in outdoor air without harming public health. The CAA requires the EPA to review and, if necessary, revise each of the NAAQS at five-year intervals to ensure that they are based on the most recent scientific findings (CARB, n.d.-b). The EPA establishes these standards through a regulatory process which includes panels of leading scientists. This process, like most regulation development processes, provides the public with the opportunity to comment on the proposed NAAQS.

States are then required to develop SIPs to demonstrate how they will either attain or maintain compliance with the NAAQS for each pollutant. A SIP is a collection of regulations and documents used by a state, territory, or local air district to implement, maintain, and enforce the NAAQS (EPA, 2023a). For example, if a state needed to decrease the concentration of ozone in its air to meet a standard, it would work to identify the sources of NO_2 and VOC emissions (ozone precursors) within the state and develop regulations aimed at reducing those emissions.

In addition to emission sources within a state, some states also have to consider cross-state air pollution. Cross-state air pollution, also known as interstate air pollution or transported air pollution, involves the transport of pollutants from one location (upwind) to another location (downwind). For example, emissions of SO_2 and NO_2 from upwind sources can undergo chemical reactions in the atmosphere to form $PM_{2.5}$, and NO_2 emissions can react in the atmosphere to create ground-level ozone pollution. These pollutants can travel great distances (i.e., hundreds of miles), affecting regional air quality and public health and making it difficult for downwind states to meet health-based air quality standards for $PM_{2.5}$ and ozone (EPA, 2024u).

The CAA contains language discussing cross-state air pollution. For example, one section of the law – known as the "good neighbor provision" – requires each state's SIP to prohibit emissions that will interfere with the attainment or maintenance of a NAAQS in a downwind state. The CAA requires EPA to create Federal Implementation Plans (FIPs) in the event that states fail to submit SIPs or submit inadequate good neighbor SIPs (EPA, 2024t).

When the CAA was first passed as law in 1970, one of the goals was to set and achieve compliance with the NAAQS in every state by 1975. However, these goals were not achieved within the target timeframe. The CAA has since been amended in 1977 and 1990 to set new goals for achieving the NAAQS. The NAAQS continue to be revised – with the most recent change involving a reduction of the annual standard for $PM_{2.5}$ in early 2024 – as better data becomes available. As the standards have incrementally decreased, many states continue to face challenges in ensuring clean air for their citizens.

The next section discusses the impact that high concentrations of ozone can have on human health and the environment.

Section Two: Ozone Pollution Impacts

Health Impacts

While all the criteria air pollutants pose potential health and environmental effects, ozone presents the most evident effects in Delaware. Ozone is a primarily colorless gas and can be harmful to our health—typically on hot, sunny days when ozone can reach unhealthy levels. Even relatively low levels of ozone (70 parts per billion or ppb) can cause adverse health effects. People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to ozone. Children are especially vulnerable since their lungs are still developing and they are more likely to have asthma.

Breathing in ozone can result in a variety of side effects. Many of these side effects will appear as the following:

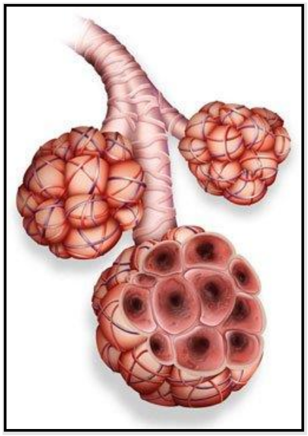
- Symptoms such as
  - Chest Pain
  - Coughing
  - Throat Irritation/soreness
  - Congestion

- Can cause
  - Increased severity or frequency of lung diseases (see Figure 5)
  - Asthma attacks
  - Pain and shortness of breath

- Can affect the lungs in the following ways
  - Inflammation of the airways
  - Damaging of the lung linings (see Figure 6)
  - Production of scar tissue
  - Increasing likelihood of infection
  - Continuous damage past the initial symptoms (EPA, 2024g, 2024h)

Figure 5

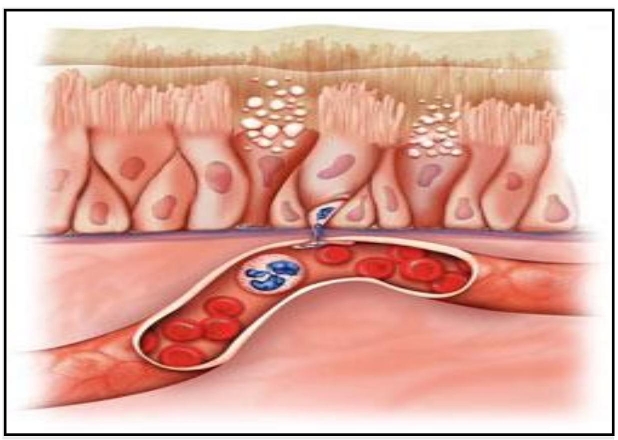
Lung alveoli – the tiny air sacs where oxygen and carbon dioxide are exchanged between the blood and air



Note. Ozone can cause the muscles in the airways to constrict, trapping air in the alveoli. This leads to increased severity of lung diseases such as Asthma, Emphysema, and Bronchitis. From EPA, 2024, April 9, Health Effects of Ozone Pollution, https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution

Figure 6

Lung airway lining



Note. When ozone enters the lungs, the airway can get inflamed, causing an influx of white blood cells. As a result the body produces more mucus and fluid which kills and sheds the lining of the lung airways. From EPA, 2024, April 9, Health Effects of Ozone Pollution, https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution

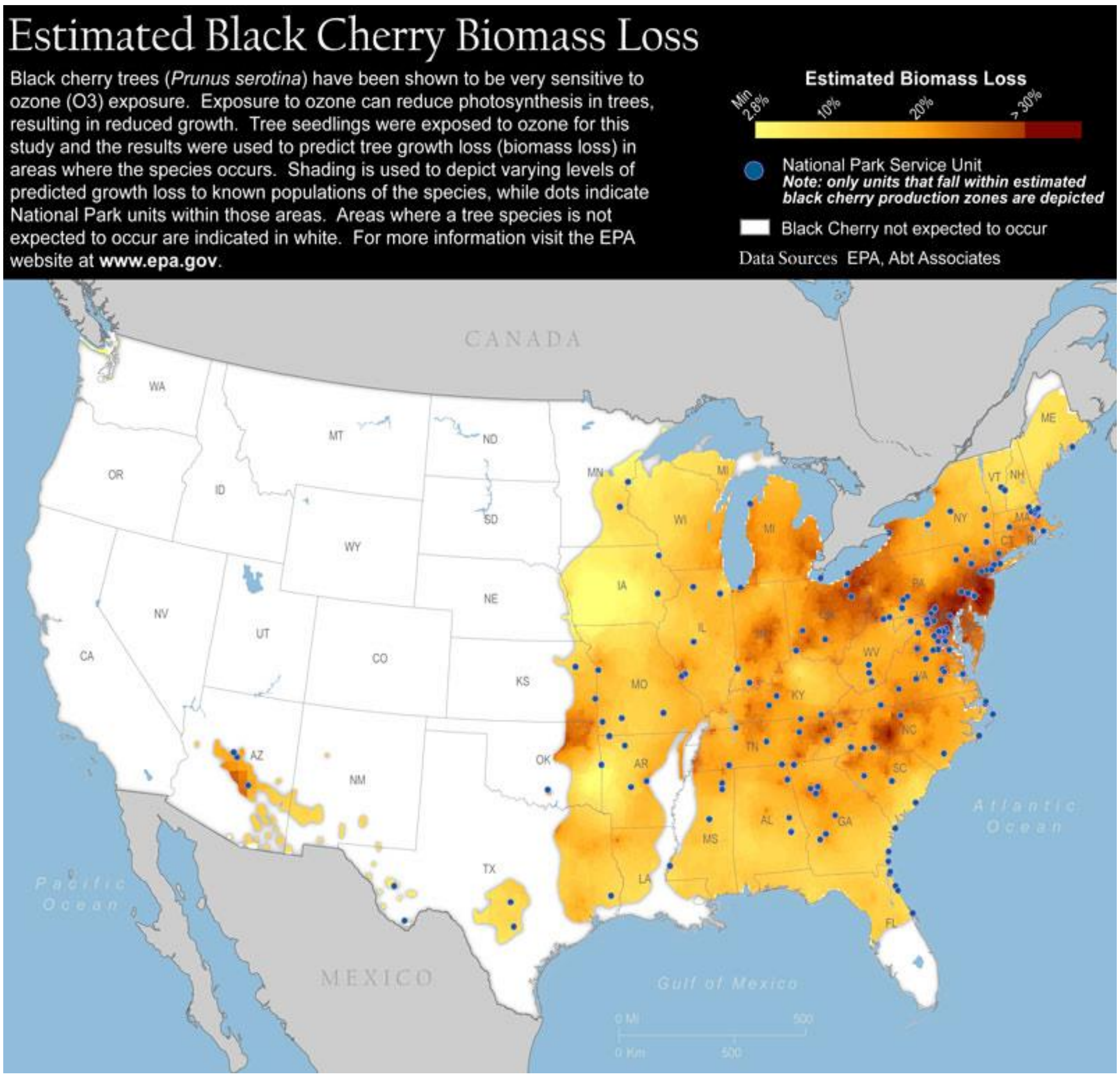
Environmental Impacts

Aside from impacts on human health, ozone also effects vegetations and the surrounding ecosystems. These ecosystems often include forests, parks, wildlife refuges, and wilderness areas. Ozone in particular, harms the trees and plants located within these ecosystems during periods of growth.

There are a variety of plant species that are susceptible to ozone exposure, but the ones that are at increased risk are trees. Black Cherry (see Figure 7), Quaking Aspen, Ponderosa Pine and Cottonwood trees are especially sensitive to ozone exposure (National Park Service, 2018b).

Figure 7

Estimated Black Cherry biomass loss



Note. National Park Service's illustration of areas with Black Cherry biomass loss due to ozone exposure. From National Park Service, (2018, November 5). Ozone effects on tree growth. U.S. Department of the Interior, National Parks Service. https://www.nps.gov/subjects/air/nature-trees.htm

Since these trees are particularly at risk, they exhibit a variety of symptoms and effects such as:

- Reduced photosynthesis
- Slow plant growth
- Oxidized/Burnt plant tissue
- Increased risk of…
  - Disease
  - Damage from insects
  - Effects from other pollutants
  - Harm from severe weather
  - Loss of species
  - Changes to habitat water and nutrient cycles

Section Three: How are Pollutants Detected?

The best way to help manage the effects of ozone and other air pollutants begins with measuring the concentration in the air we breathe. The EPA requires ambient air monitoring, which is the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding, outdoor air. Ambient air monitoring is an integral part of an effective air quality management system. Reasons to collect such data include to:

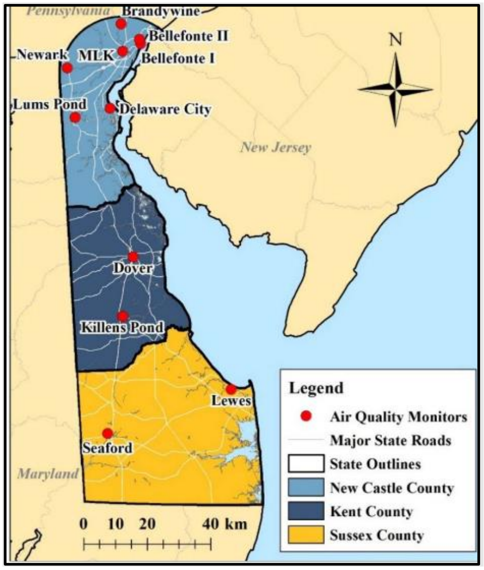
- assess the extent of pollution;
- provide air pollution data to the general public in a timely manner;
- support implementation of air quality goals or standards;
- evaluate the effectiveness of emissions control strategies;
- provide information on air quality trends;
- provide data for the evaluation of air quality models; and
- support research (e.g., long-term studies of the health effects of air pollution) (EPA, 2024j).

Most of the ambient air monitoring networks supporting air quality management are designed and operated by tribal, state, or local governments such as DNREC. EPA develops requirements and guidance for various aspects of these networks which it publishes in the Code of Federal Regulations (CFR).

The monitoring stations in this network are called the State and Local Air Monitoring Stations (SLAMS). The SLAMS were established to allow state or local governments to develop monitoring networks tailored more to their immediate ambient air monitoring needs related to the SIP. The State of Delaware operates 11 monitoring sites throughout the state to measure air pollutants. The location of these sites are shown in Figure 8 along with images showing the external (Figure 9) and internal (Figure 10) components of the stations.

Figure 8

Illustration of the current ambient air monitoring network in Delaware



Note. From Delaware DNREC. (2024, May). Delaware Ambient Air Network Monitoring Plan for Criteria Pollutants (p.11). https://documents.dnrec.delaware.gov/Air/monitoring/delaware-air-monitoring-network-plan.pdf

Figure 9

Ambient air monitoring station in Seaford, Delaware

Note. From Delaware DNREC. (2024, May). Delaware Ambient Air Network Monitoring Plan for Criteria Pollutants (p.38). https://documents.dnrec.delaware.gov/Air/monitoring/delaware-air-monitoring-network-plan.pdf

The SLAMS network includes all permanent monitoring stations in addition to National Core (NCore) sites, Photochemical Assessment Monitoring Stations (PAMS), and Chemical Speciation Network (CSN) stations (Ambient Air Quality ("Ambient Air Quality," 2024). NCore sites must meet more stringent monitor siting, equipment type, and data completeness criteria; PAMS sites conduct specific to monitoring for parameters that affect or contribute to ozone formation; CSN sites perform enhanced PM monitoring and characterization.

In 2006 the EPA required the establishment of NCore monitoring stations to begin operating in 2011. NCore is a national multi-pollutant network that integrates several advanced measurement systems to enhance ambient air quality monitoring and better serve current and future air quality needs. NCore sites are also required to detect several pollutants at lower levels than other stations. Delaware's Wilmington site, MLK, shown in Figure 10, was configured to meet NCore requirements and began monitoring in 2010.

Figure 10

NCore criteria gas analyzers located in the MLK site

Note. From Delaware Department of Natural Resources and Environmental Control, 2019, Delaware Annual Air Quality Report (p.33), https://documents.dnrec.delaware.gov/Air/monitoring/2019-Delaware-Annual-Air-Quality-Report.pdf

The PAMS program was originally required by the 1990 CAA Amendments for enhanced monitoring of ozone for areas not attaining the ozone NAAQS. The main objective of the PAMS sites is to develop a database of ozone precursors and meteorological measurements to support ozone model development and track the trends of important ozone precursor concentrations (EPA, 2024l). Revisions to the PAMS requirements were made in 2015, to update the technology and meet the needs of PAMS users. The NCore site at the MLK began serving as the PAMS site for Delaware in 2023. PAMS data is collected from June 1st through August 31st annually.

Seven of the Delaware air monitoring stations are ozone monitoring sites. These sites were selected for population exposure, background concentrations, upwind and downwind directions for the Wilmington area, and NCore monitoring. The ozone monitors began operating year-round in 2011 although the official EPA ozone monitoring season for Delaware runs from March through October (Delaware Department of Natural Resources and Environmental Control [DNREC], 2024, p. 15).

Now that we know where ozone and other pollutants are measured, let's take a deeper look on how ozone is measured and detected.

Measurement and Detection of Ozone

Ozone has both beneficial and detrimental effects on human health and the environment. Ozone occurs naturally in the upper atmosphere (stratospheric ozone, also called the ozone layer) and protects humankind against skin cancer caused by ultraviolet radiation from the sun. Ozone resulting from human activity at or near ground level (tropospheric ozone) is the principal constituent of smog, which adversely affects respiratory health, agricultural crops, and forests.

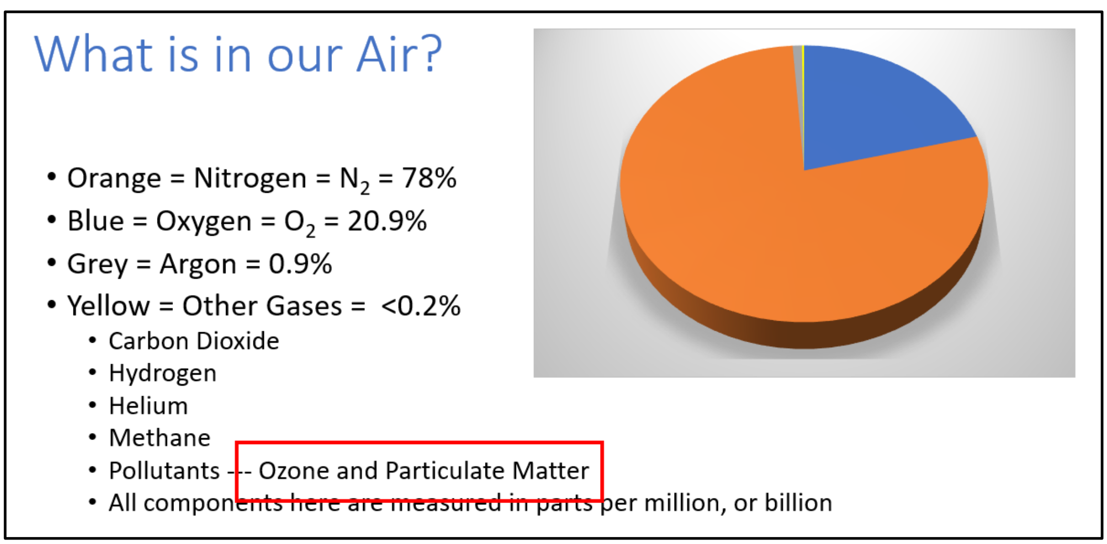
Ozone in smog is formed by sunlight reacting with NO_X, a by-product of fuel combustion emitted by sources like diesel and gasoline-powered vehicles, and VOCs discharged into the air from gasoline vapors, solvents, fuel combustion, and consumer products. The sources for these VOCs include common household products, oil-based paints, large industrial plants, gas stations, motor vehicles, dry cleaners, etc. There are natural sources of VOCs as well, including wildfires and certain plants and trees (Center for Science Education, n.d.; EPA, 2018; Institute for Arctic and Alpine Research, n.d.).

These ozone-forming components affect not only the areas where they are generated, but are frequently transported by atmospheric conditions from one area to another where the ozone-producing reactions actually occur. For example, NO_X and VOC may float with the winds from Richmond to Wilmington, or Baltimore to Seaford, to form ground-level ozone.

Detection of pollutants can be difficult since most of these materials are present in the environment at low concentrations (see Figure 11).

Figure 11

The composition of gases that make up the air we breathe



Note. Created by Angela Marconi, Director, DNREC Division of Air Quality for a classroom presentation

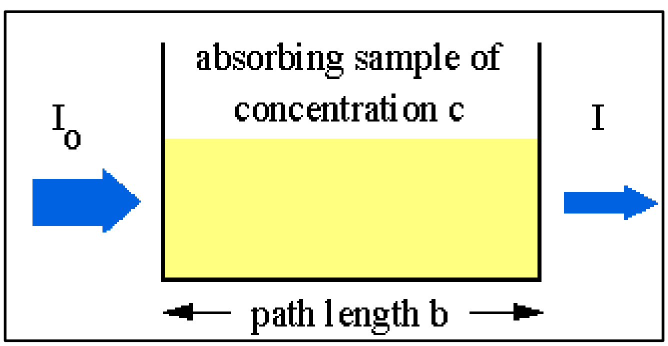
When the CAA was enacted in the 1970's, pollutants were present in higher concentrations than they are currently. In the State of Delaware, pollutant concentrations have decreased over time due to regulation; lower concentrations are more difficult to measure than higher concentrations. The current range is in the parts per billion or lower, due to the success of the CAA. The next paragraph then discusses the techniques needed to measure these low concentrations of pollutants.

Techniques to detect pollutants must be sensitive enough to analyze these materials at very low concentration levels. These techniques must also be free from interferences that would result in false positive or false negative responses. Techniques have been developed to specifically analyze many materials of interest. These methods typically use some form of light energy as the basis of measurement.

In the case of ozone, the technique developed uses the absorption of ultra-violet (UV) light as shown in Figure 12. This method operates on the principle that ozone molecules absorb UV light at a wavelength of 254 nanometers (nm). The degree to which the UV light is absorbed is directly proportional to the ozone concentration as described by the Beer-Lambert Law. The Beer-Lambert law (or Beer's law) is the linear relationship between absorbance and concentration of an absorbing species. Environmental measurements are usually made in terms of concentration (C), which is defined as $\mathbf{C = I / I_o}$, where **I** is the light intensity after it passes through the sample and $\mathbf{I_o}$ is the initial light intensity.

Figure 12

Absorption of light by a sample



Note. From HK Technical, n.d., Lamber's Law – definition, explanation, equation, derivation, https://pgims.hktechnical.com/lamberts-law-definition-explanation-equation-derivation/

Modern instruments can display the data as concentrations of either part per million (ppm) or ppb. Unknown concentrations of ozone are determined by comparing the amount of light that a known ozone sample (calibration standard) absorbs to the unknown ozone concentration.

For ozone measurements to be accurate, analyzing instruments must be periodically calibrated to a known verified standard. The calibration of measuring instruments must be done in strict accordance with the EPA guidelines in order to be relevant when compared to measurements at other sites locally and regionally. The analyzer must be calibrated once every calendar quarter or after any material repair of the instrument. Regular checks are performed at least every 14 days to verify operation of the instrument. A rigid audit program also verifies the operation of the instrument against an independent certified ozone photometer standard, separate air source, and a separate operator.

The ozone calibration photometer uses a UV lamp to generate ozone. The intensity of UV light changes as the electric current is varied on the UV lamp. One additional parameter to control is the amount of air that is being "ozonated." If a constant volume of air flows through a chamber with a UV light at a constant voltage, a constant concentration of ozone will be produced.

The calibration process begins with introducing a sample that is free of pollutants. This is called zeroing the instrument. This zero gas is typically air that is supplied by a compressor. The compressed air is passed through several filters and scrubbers to remove all pollutants and is referred to as "zero air". After the monitoring instrument samples the zero air for a suitable time to obtain a stable baseline, the instrument's signal is adjusted to read zero.

The analyzer is then challenged with a known concentration of ozone. A high concentration test is known as a span test, whereas sampling a lower or near-ambient concentration level is called a precision test. The span concentration that is generated should be in the area of interest that needs to be monitored. The current EPA primary and secondary standard for ground-level ozone is 0.070 ppm.

When monitoring ozone concentrations in the atmosphere for environmental compliance, only EPA approved instruments and methodologies may be used. This approval is obtained by passing a series of tests to assure analytical accuracy and data validity. Once the equipment and methodology are approved for use, the results are published and a notice is printed in the CFR. All data collected for EPA compliance must use analyzers certified as an EPA Equivalent or Reference Method.

To obtain accurate measurements, any analyzer must be operated in a climate-controlled environment which maintains electronic stability. Climate control also helps prevent water vapor from condensing in the instrument. Air samples must be filtered of PM to keep optical elements in the analyzer clean. Figure 13 shows monitoring instrumentation mounted in an ambient air monitoring station.

Figure 13

DNREC field personnel discussing instrument operation

After ambient air monitoring data is collected, it is reviewed by the Quality Assurance (QA) Coordinator. The QA Coordinator reviews data on a daily basis to assure the accuracy of data collected.

AQ reports data directly to EPA. The AirNow.gov website is available to the public to view pollutant concentrations in every state. Data from all of Delaware's ambient air monitoring stations is sent to AirNow on an hourly basis.

The data from EPA monitoring programs, state monitoring programs, and other sources is used by individual states to determine the impact of air pollutants on the environment. AQ uses this data to draft SIPs to reduce the impact of air pollutants on public health. Accurate and precise data from air quality monitors is essential for the control of air pollutants and maintaining a healthy environment for the citizens of Delaware.

New Directions in Collecting Ambient Air Data

Due to the importance of accurate and precise measurements of air pollutants to air quality management planning, AQ had developed a Moveable Monitoring Platform (MMP) so state-of-the-art monitoring equipment could be placed wherever it was needed without the requirement for building site-specific infrastructure. The MMP was a vehicle that contained monitoring equipment, as shown in Figures 14 and 15, for most criteria pollutants, select air toxics, and meteorological data (DNREC, n.d.).

Figures 14 and 15

Analyzers installed inside of the MMP, and looking towards the rear of the vehicle

The MMP gave AQ the flexibility to deploy powerful monitoring instruments that may otherwise require lengthy setup periods. This flexibility allowed AQ to respond to community concerns with EPA approved monitoring instruments and techniques. For example, beginning in 2016 AQ conducted an extensive, multi-year air monitoring study in Eden Park using the MMP. Residents of Eden Park were concerned with the levels of “dust” and other pollutants in the ambient air, so AQ used the MMP to collect criteria pollutant data (including fine PM), total suspended particulates (TSP, also called “dust”) and meteorological data in the local area. PM data collected by the MMP determined that the criteria pollutants (including fine PM) did not exceed the NAAQS in this community, however the ambient level of TSP in the air in Eden Park was significantly higher than the MLK site, where TSP is also measured. This data, along with meteorological data, was used in further studies to determine the sources/causes of the TSP. DNREC then used the information to implement updated dust control plans for local industry and to encourage additional voluntary actions including street sweeping and the use of truck cleaning stations (DNREC, 2021).

The MMP has recently taken a hiatus; AQ plans to invest in a new mobile monitoring vehicle that utilizes an electric motor rather than an internal combustion engine. Until then, special projects that require a mobile monitoring station are on hold.

With the development and miniaturization of processors and detectors has come the development of micro-instruments that can be used to monitor air quality. These instruments, referred to as "air quality sensors," have become a great tool for citizen scientists and those with sensitivity to certain air pollutants. As these instruments become more widely available, air quality sensors will become an even more important tool to empower the community to help maintain Delaware's air quality.

Air Sensors

A new generation of low-cost and highly portable air quality sensors opens an exciting opportunity for people to gather crude measurements at home or in areas of specific interest. The technology, once better developed and vetted against traceable standards, opens a wide range of applications beyond traditional, regulatory monitoring (EPA, 2024i). Currently, sensors are being widely deployed to measure PM. One type of sensor, purpleair, provides data to EPA’s Airnow.gov tool through the Fire and Smoke map. This is accessible at https://fire.airnow.gov/ or on the Airnow app. The Fire and Smoke Map shows SLAMS data as large circles, and sensor data as small circles. Throughout Delaware these air quality sensors are hosted by private residents, New Castle County facilities, Public Libraries and at DNREC’s AQ office in New Castle.

The EPA has specific guidelines for regulatory-grade air *monitors* which have yet to be met by the lower cost citizen science-grade *sensors* currently available. While these tools are in an early stage of development and are still being evaluated, such private-user instruments are still valuable tools for the public. These sensors can be used to protect personal health and empower community members to advocate for better air quality.

Table 2 summarizes some potential non-regulatory application areas for air sensors and provides brief descriptions and examples (EPA, 2024i).

Table 2

Summary of some potential non-regulatory uses for air sensors

APPLICATION	DESCRIPTION	EXAMPLE
Research	Scientific studies aimed at discovering new information about air pollution.	A network of air sensors is used to measure PM variation across a city.
Personal Exposure Monitoring	Monitoring the air quality that a single individual is exposed to while doing normal activities.	An individual having a clinical condition increasing sensitivity to air pollution wears a sensor to identify when and where they are exposed to pollutants potentially impacting their health.
Supplementing Existing Monitoring Data	Placing sensors within an existing state/local regulatory monitoring area to fill in coverage.	A sensor is placed in an area between regulatory monitors to better characterize the concentration gradient between the different locations.
Source Identification and Characterization	Establishing possible emission sources by monitoring near the suspected source.	A sensor is placed downwind of an industrial facility to monitor variations in air pollutant concentrations over time.
Education	Using sensors in educational settings for science, technology, engineering and math lessons.	Sensors are provided to students to monitor and understand air quality issues.
Information /Awareness	Using sensors for informal air quality awareness.	A sensor is used to compare air quality at people's homes or work, in their car, or at their child's school.

Note. Created by staff using data from EPA, 2024, November 20, How to Use Air Sensors: Air Sensor Guidebook, https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

Section Four: The Air Quality Index

The Air Quality Index, more commonly known as the AQI, is the EPA's index for reporting air quality. The AQI provides a numerical value (ranging from 0 to 500) that communicates how clean or polluted the air is, and what associated health effects might be a concern for you. Those numeric values are then grouped into categories. For ease of use, the categories are color-coded, as shown in Table 3, and provide statements about local air quality, which groups of people may be affected, and steps people can take to reduce their exposure to air pollution.

The EPA establishes an AQI for each of the five major air pollutants regulated by the Clean Air Act (CO, NO_2, ozone, PM and SO_2). The AQI for each pollutant draws on the scientific information that supports the health-based NAAQS for that pollutant. For example, an AQI value of 100 generally corresponds to an ambient air concentration that equals the level of the short-term NAAQS for the protection of public health, while AQI values at or below 100 are typically thought of as satisfactory. When AQI values are above 100, air quality is unhealthy – at first for certain sensitive groups of people, then for everyone as AQI values get higher (EPA, 2024o).

Table 3

Air Quality Index

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Note. Created by staff using data from EPA, 2024, May, Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI), https://document.airnow.gov/technical-assistance-document-for-the-reporting-of-daily-air-quailty.pdf

The AQI is available in different formats – both as a forecast (predicting future conditions) and in real-time (reporting current conditions). The following sections will discuss each.

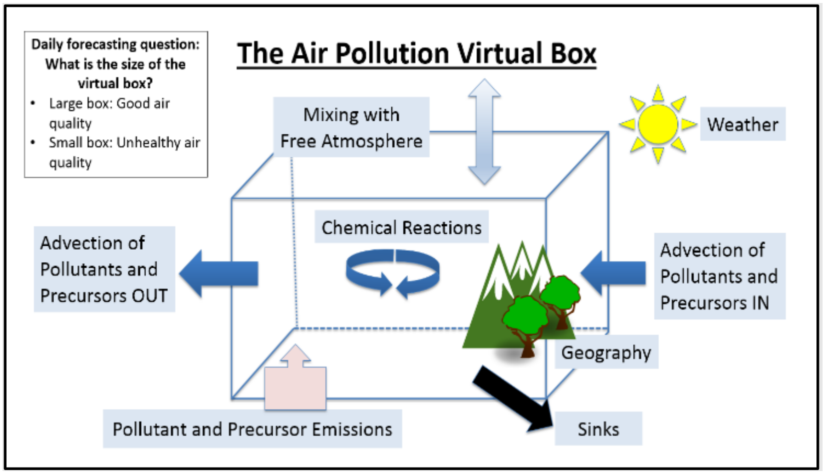
AQI Forecasts

AQI Forecasts are a prediction of future air quality using the AQI colors and scale. Forecasts are issued by state, tribal, and local air quality forecasters in the afternoon for the next day. Forecasts heavily depend on temperatures, precipitation, wind, and cloud cover. Weather affects pollution creation and transport from other areas. The AQI forecasts enhance human health by helping residents avoid risks from air pollution.

Forecasts are complicated, and forecasters have a number of tools at their disposal. Air quality forecasting begins by creating a detailed weather forecast. Ozone, for example, is formed photochemically – by the combination of chemical reactants and sunshine – warm sunny days are generally necessary for high ozone. However, because of better air quality, it’s no longer as simple as just looking at the maximum temperature for the day. A forecaster has to combine their weather predictions, understanding of how much ozone precursor pollution will be blown in from upwind areas, and how much precursor pollution will be emitted in Delaware. You can think of it as a box like the one shown in Figure 16. If you have a large box, with lots of clean air and few emissions, then you have dilute pollutants, and relatively low ozone concentrations. A small box, with lots of pollutants and little clean air to mix with will lead to high ozone concentrations.

Figure 16

Illustration depicting what is considered in air quality forecasts



Note. Provided by Dr. Amy Huff, Assistant Research Professor, Dept. of Meteorology and Atmospheric Science, The Pennsylvania State University, 2018

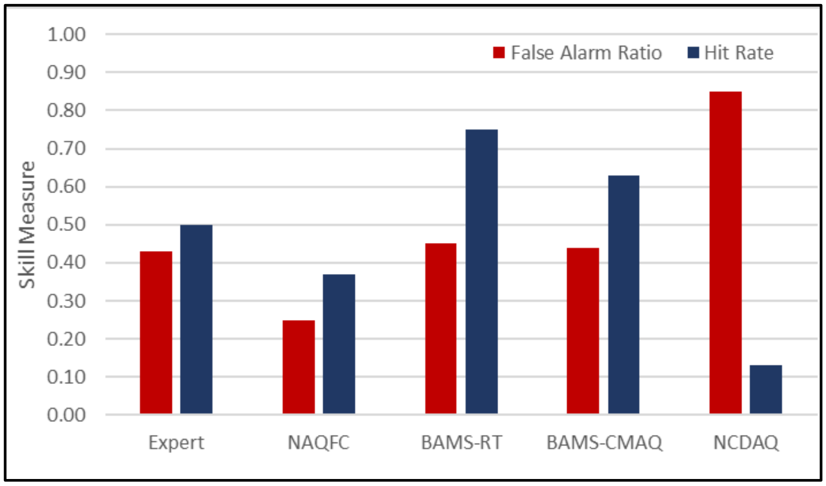
After creating the weather forecast and predicting both the advection of pollutants and the emission of pollutants, the forecaster will assign a prediction to the next day. After all of this, then the forecaster will consult the numerical models available that predict the ozone concentration. They consult this last in order to compare and contrast their own projections to what the models say (S. Cone, personal communication, October, 2018). For ozone, an AQI forecast focuses on the period during the day when average 8-hour ozone concentrations are expected to be the highest. For PM, the forecast predicts the average 24-hour concentration for the next day (Air Now, n.d.).

Another thing to consider is that the landscape of air quality changes over time. For example, at present, mobile sources make up a bigger portion of pollution than point sources, for some pollutants, and the overall amounts of NO_X and VOC emitted are trending downward. Therefore, the models have to adapt to accurately predict high AQI days. After each ozone forecasting season (May – September), the forecasters will review the models, and see which models were most effective in predicting high ozone. When a model is reviewed, two of the most important measures are Hit Rate (the number of high ozone days that the model correctly predicted) and False Alarm Ratio (the number of days the model predicted high ozone when there was not high ozone).

Figure 17 shows expert performance and model performance for four different models for the max 8-hour ozone prediction in Delaware in 2017. In this case, a high blue value and a low red value is best. In 2017, the Bulletin of the American Meteorological Society Radiative Transfer (BAMS-RT) model actually outperformed the expert forecasters. However, this same model did much worse in 2016, and so the experts did not blindly accept this model's predictions. This shows just how tough it can be to accurately predict air quality.

Figure 17

Performance of expert forecasters compared to model forecasting



Note. Models depicted are National Air Quality Forecast Capability (NAQFC), Bulletin of the American Meteorological Society Radiative Transfer (BAMS-RT), Community Multiscale Air Quality Modeling (CMAQ), and North Carolina Division of Air Quality (NCDAQ). Adapted by using data provided by Dr. Amy Huff, Assistant Research Professor, Dept. of Meteorology and Atmospheric Science, The Pennsylvania State University, 2018

AQI forecasting in Delaware is performed for ozone and $PM_{2.5}$ and currently runs from May 1st through September 30th of each year. For more information, check out DNREC's Air Quality Forecast page, where you can sign up to receive air quality email alerts.

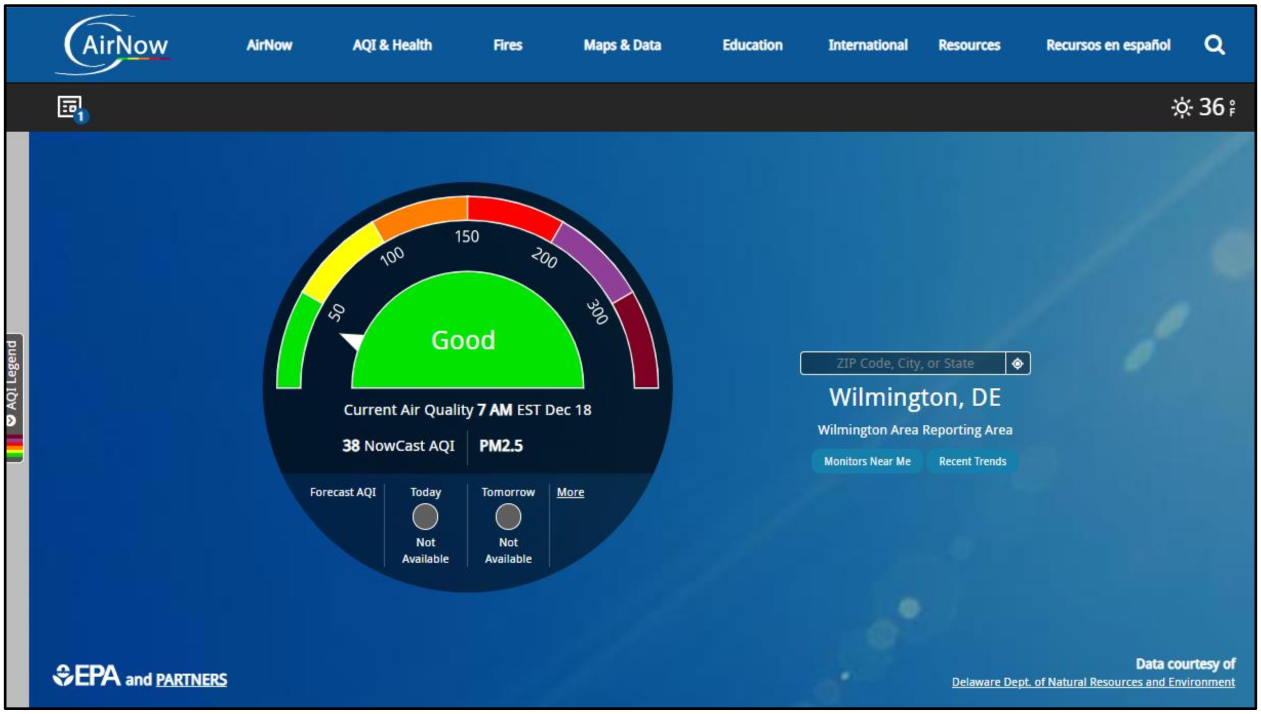
Real-Time AQI

In addition to the forecast, a version of the AQI is also available in real time. The EPA's AirNow website and the AirNow mobile app provide the “AQI NowCast” – an index that reports what the air quality is at that moment in time for a location. The NowCast is EPA's method for relating hourly data to the AQI. EPA calculates a NowCast for two pollutants – ozone and PM – and shows you air quality for the most current hour available by using a calculation that involves multiple hours of past data (see figure 18).

The NowCast is designed to be responsive to rapidly changing air quality conditions, such as during a wildfire. The NowCast calculation uses longer averages during periods of stable air quality and shorter averages when air quality is changing rapidly. The NowCast allows AirNow's current conditions to align more closely with what people are actually seeing or experiencing. This gives people information they can use to protect their health when air quality is poor – and help them get outdoors and get exercise when air quality is good (EPA, n.d.-a).

Figure 18

Screenshot of the EPA AirNow website showing the AQI information for Wilmington, Delaware



Note. From AirNow, n.d., EPA, retrieved December 18, 2024, from https://www.airnow.gov/

How To Use The AQI

The AQI forecast and real-time data should be used to help plan your outdoor activities for the day. Much like a weather forecast lets people know whether to pack an umbrella, an air quality forecast lets people know when they may want to change their outdoor activities to reduce the amount of air pollution they breathe in. Many forecasters also provide a “forecast discussion,” which lets people know when pollution is expected to be highest during the day – and if there are times when air quality is expected to be better.

For example, the AQI may be forecasted to be in the Orange (unhealthy for sensitive groups) level for ozone on a given day, but the forecast suggests that those conditions might not occur until the afternoon. You decide to check the AQI NowCast in the morning and find that the AQI is currently in the Green (good) level. Knowing this information, you can safely take advantage of the period of good air quality to enjoy some outdoor activities.

As the day progresses and ozone precursors (like NO_2 and VOCs) are emitted or transported into your area and react photochemically to form ozone, the AQI may increase. By keeping an eye on the AQI NowCast, you can safely adjust your activities, ensure you are prepared with your medication (such as an asthsma inhaler) and go inside when the AQI is approaching levels that are unhealthy.

It's important to note that different concentrations of air pollutants can impact people differently. For example, an AQI in the Orange level is considered to be unhealthy for members of sensitive groups (e.g., people with heart or lung disease, such as asthma; children; people who are active outdoors; and older adults), but the general public is less likely to be affected. To better understand the risks of each AQI category, the EPA has published the following guides:

- Air Quality Guide for Particle Pollution
- Air Quality Guide for Ozone
- Air Quality and Outdoor Activity Guidance for Schools

These documents provide guidance to the affected populations at each AQI level and as well as background about the pollutants, how to protect yourself, and how to reduce emissions. Speaking of reducing emissions, the following bullets provide some examples of how you can minimize your impact on air quality:

- Ride public transportation
- Carpool with friends and/or coworkers
- Walk or ride a bicycle
- When you must drive:
    - Limit daytime driving and combine errands
    - Try to avoid congested periods
    - Maintain your vehicle's emission control equipment
    - Refuel your car in the evening – and don't top off your tank.
    - Avoid prolonged idling and jackrabbit starts (sudden, rapid acceleration).
- Postpone the use of gasoline-powered mowers until evening
- Avoid lighting your barbecue with starter fluid.
- Use latex paint rather than oil-based paints.

DNREC also uses the AQI forecast to minimize emissions on days where the AQI is expected to be in the Orange (unhealthy for sensitive groups) level and above for ozone or $PM_{2.5}$. On days when those conditions are forecasted, DNREC's regulations and permits prohibit the use of specific equipment for non-emergency purposes before 5pm on days when an air quality alert has been issued. These efforts help to reduce the emission of pollutants that would negatively impact the AQI on those days.

How the AQI is Calculated

The AQI is calculated by converting measured pollutant concentrations to a uniform index which is based on the health effects associated with a pollutant. The health benchmarks used for calculating the AQI are pollutant specific and are established by the EPA through the National Ambient Air Quality Standards. Something to note, however, is the AQI in different areas may be comprised of different pollutants. This is because the EPA has advised that if the AQI for one pollutant is in the Green (good) level, then you can exclude that pollution from your calculations. While the AQI may be calculated for multiple pollutants, the value that you see reported is for the "primary pollutant" – the pollutant with the highest calculated AQI at the time.

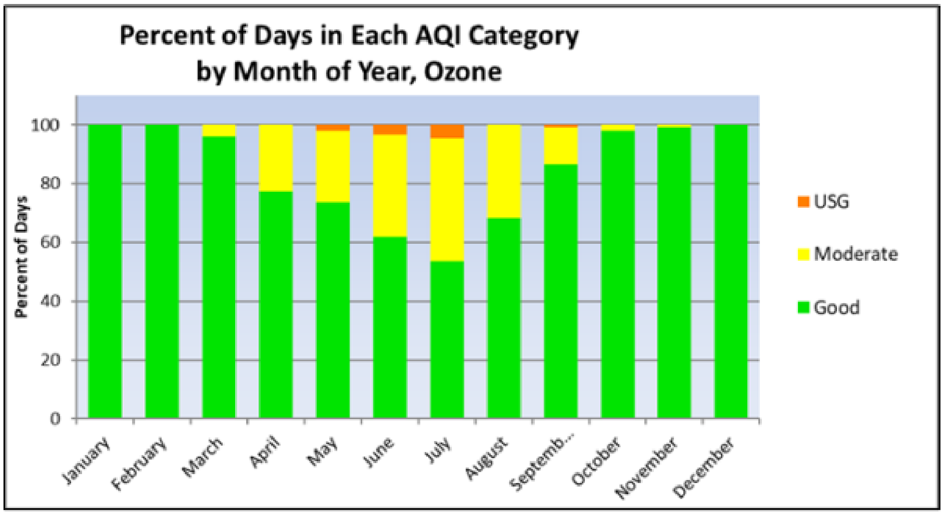
The AQI and Delaware

Now that we've provided some background on the AQI, let's talk a little bit about how it relates to Delaware. Due to the long-term reductions in regional emissions, AQI levels for ozone in

Delaware are generally in the Green (good) level for most days during the year. Figure 19 shows that based on data collected from 2018 through 2022, Delaware's air quality was in the Green (good) level on 85% of days. During the summer air quality forecast period of May-September, nearly 70% of days featured Green (good) AQI levels (Beamish et al., 2024).

Figure 19

Monthly distribution of each AQI category based on 2018-2022 ozone data



Note. From Beamish, J., Irwin, S., & Zahn, P., 2024, April 19, State of Delaware Final Report: Ozone and PM2.5 Observations and Forecasts in 2023 (p.4) DNREC. https://documents.dnrec.delaware.gov/Air/ozone-reports/DE-Ozone-PM-2023.pdf

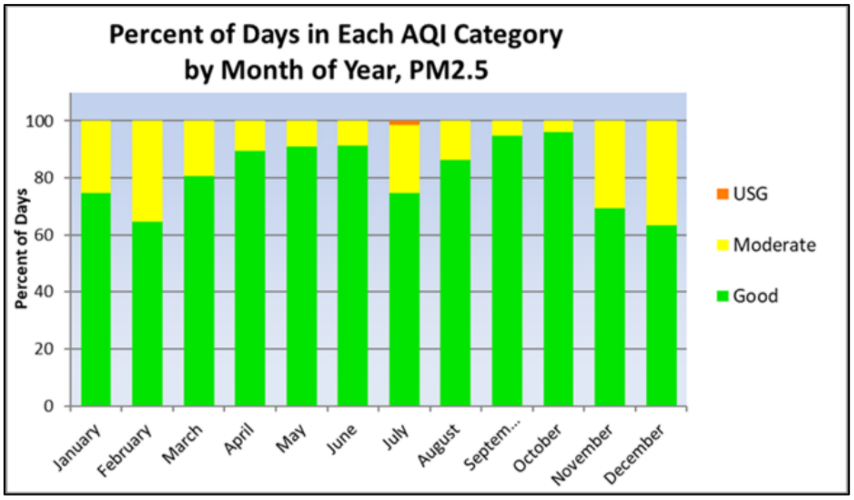
A clear pattern emerges for months when AQI levels for ozone in the Yellow (moderate) level or above are recorded more frequently. Based on the 2018-2022 data, the occurrence of days with an ozone AQI at or above the Yellow (moderate) level is most frequent in June and July, when surface temperatures are at their seasonal warmest and when days are longest. These meteorological conditions, combined with regional emissions, result in higher concentrations of ground-level ozone in Delaware.

While infrequent, days with an ozone AQI value in the Orange (unhealthy for sensitive groups) level (otherwise referred to as "Code Orange" or "Ozone Action" days) can also occur. During the 5-yr period from 2018-2022, Code Orange days for ozone occurred most frequently in July, with other ozone Code Orange days occurring in May, June, and September. Annually, ozone Code Orange days account for less than 1% of all days.

During the summer air quality forecasting season, the long range transport of wildfire smoke can impact Delaware and contribute to increased concentrations of $PM_{2.5}$. Because of this, AQ issues a daily forecast for PM along with the ozone forecast. To account for smoke events, and to give meteorologists perspective on potential $PM_{2.5}$ patterns, a monthly and seasonal review of $PM_{2.5}$ AQI data was performed for the same 2018-2022 period. Figure 20 illustrates that this data shows that $PM_{2.5}$ AQI levels were in the Green (good) level on most days throughout the year. Based on the 5-yr period of $PM_{2.5}$ data obtained, days where the $PM_{2.5}$ AQI was in the Yellow (moderate) level or above occurred most frequently between November and February. This coincides with the time of year when temperatures are at their coolest, and temperature inversions (atmospheric conditions that trap pollutants near the ground) are more likely to occur than in other months.

Figure 20

Monthly distribution of each AQI category based on 2018-2022 $PM_{2.5}$ data



Note. From Beamish, J., Irwin, S., & Zahn, P., 2024, April 19, State of Delaware Final Report: Ozone and $PM_{2.5}$ Observations and Forecasts in 2023 (p.7) DNREC. https://documents.dnrec.delaware.gov/Air/ozone-reports/DE-Ozone-PM-2023.pdf

For the summer forecasting season, just 12% of days saw $PM_{2.5}$ AQI levels in the Yellow (moderate) level, and Code Orange days for $PM_{2.5}$ were recorded on only 1% of days. July recorded the highest number of days with a $PM_{2.5}$ AQI in or above the Yellow (moderate) level during the summer forecasting season, which occurred on 25% of July days between 2018-2022.

Code Orange days for $PM_{2.5}$ occurred on only two days during the 2018-2022 period. These two days occurred consecutively on July 20-21, 2021, when smoke from Canadian wildfires impacted the Mid-Atlantic region. In recent years occurrences of high summertime $PM_{2.5}$, especially during the month of July, were the result of the transport of wildfire smoke.

As we've shown, the AQI in Delaware is good on most days of the year, but how does this recent data compare to the past?

Section Five: Air Quality Trends

Air Quality Concentrations through Time

Since the implementation of the CAA in 1970, the combined emissions of the six common pollutants (CO, PB, NO_x, $PM_{2.5}$/PM_{10}, SO_2, and VOCs) dropped by 78%. As measured more recently, with the improved consistency of monitoring methodologies, national concentrations of air pollutants have dropped significantly since 1990:

- PM_{10}, 24-Hour, ↓ 29%
- SO_2, 1-Hour, ↓ 92%
- Ozone, 8-Hour, ↓ 18%
- CO, 8-Hour, ↓ 79%
- Pb, 3-Month Average, ↓ 87% (from 2010)

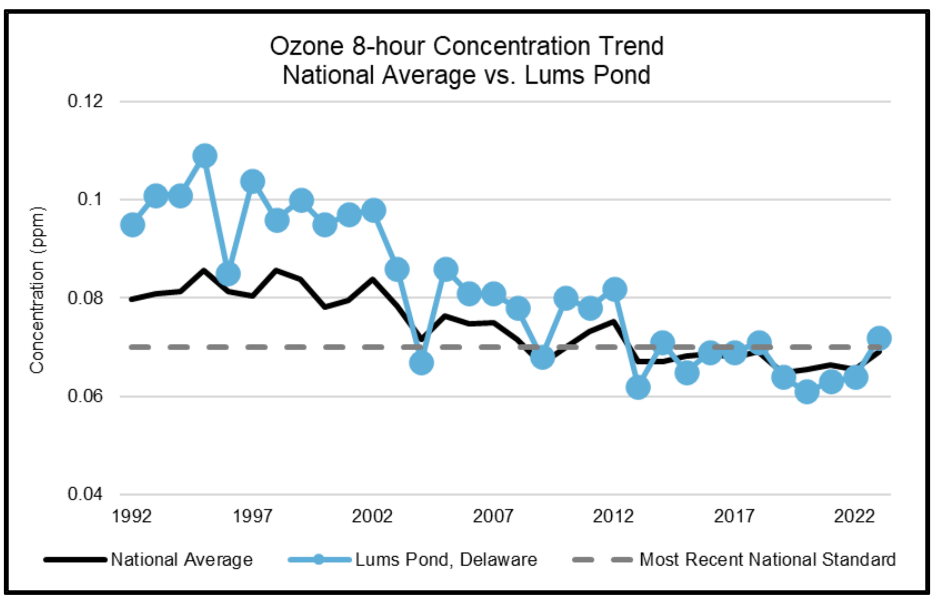
National average air quality concentrations remain below the current NAAQS. This progress toward nationally cleaner air occurred while U.S. economic indicators remain strong:

- Population Growth, ↑ 63%
- Vehicle Miles Traveled, ↑ 194%
- Gross Domestic Product, ↑ 321% (EPA, n.d.-b, pp. 1-9)

In Delaware, trends in ambient air concentrations of the criteria air pollutants have either been level or declining over recent years. These trends can be used to show clean air progress toward attaining the NAAQS. In Figure 21, the Lums Pond monitoring site shows a steadily decreasing trend in the ozone 8-hour concentration in New Castle County, which tracks with the national average and generally approaches the most recent national standard (EPA, n.d.-c, p.11).

Figure 21

National average ozone concentration compared to Delaware ozone concentration (Lums Pond monitoring site) from 1992-2022



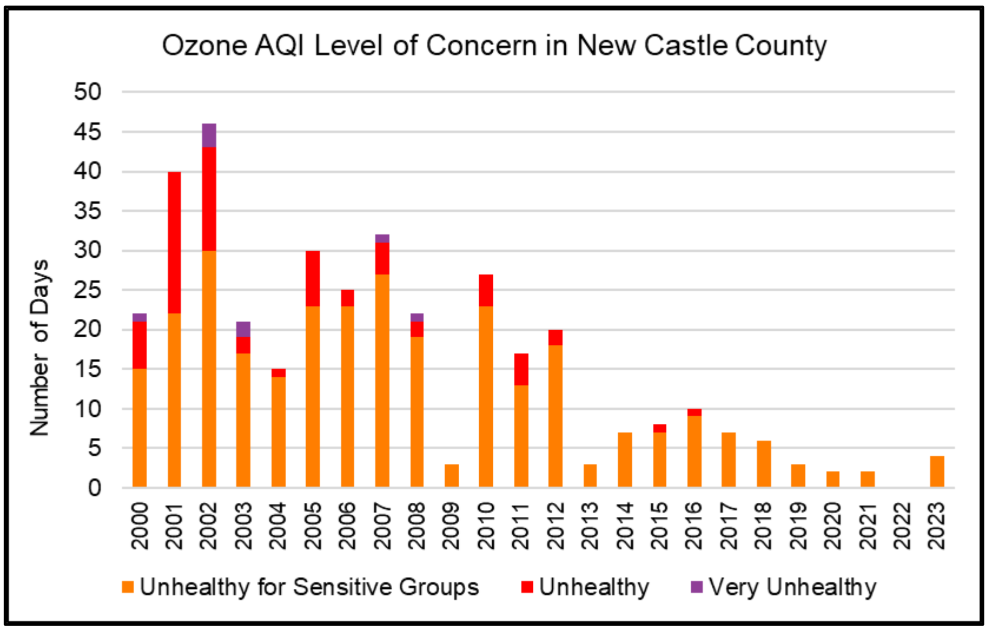
Note. Created by staff using data downloaded from EPA, Our Nation's Air: Status and Trends Through 2023, https://gispub.epa.gov/air/trendsreport/2024/#naaqs_trends

The daily AQI can also be used to evaluate the air quality improvement over time. Since 2000 (using the 2015, 70 ppb standard), the number of days in New Castle County where the ozone

AQI level of concern was Orange (unhealthy for sensitive groups), or worse, has significantly declined, as shown in Figure 22. In fact, New Castle County has not experienced a day with the ozone AQI level of Red (unhealthy) since 2016, and Purple (very unhealthy) since 2008 (EPA, 2024a).

Figure 22

Summary of the number of days over the past 23 years with unhealthy ozone levels in New Castle County, based on the 2015, 70 ppb standard



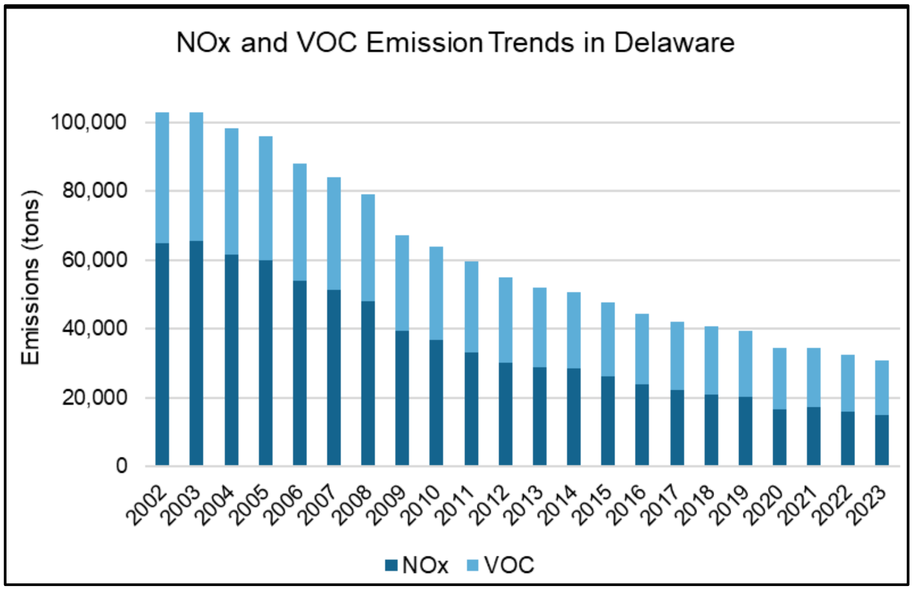
Note. Created by staff using data downloaded from EPA, 2024, November 7, Air Data - Multiyear Tile Plot, https://www.epa.gov/outdoor-air-quality-data/air-data-multiyear-tile-plot

Together with ambient monitoring data, the NEI can be used to understand changes and trends in air quality. The NEI is a comprehensive and detailed estimate of air emissions of criteria air pollutants, criteria precursors, and hazardous air pollutants from air emission sources. The EPA releases the NEI every three years, based primarily on data provided by state, local, and tribal air agencies (EPA, 2024k).

Each year, the EPA updates data for air emission trends of CAPs (except Pb). The trends data relies on the NEI and other year-specific data. For the interim years and years after the latest NEI year, EPA includes data from its emission modeling platforms (EPA, 2024p). Figure 23 illustrates that the trends data shows a steady decline in ozone precursor emissions in Delaware from 2002 to 2023 (EPA, 2024c).

Figure 23

Chart showing the decline in ozone precursor emissions in Delaware



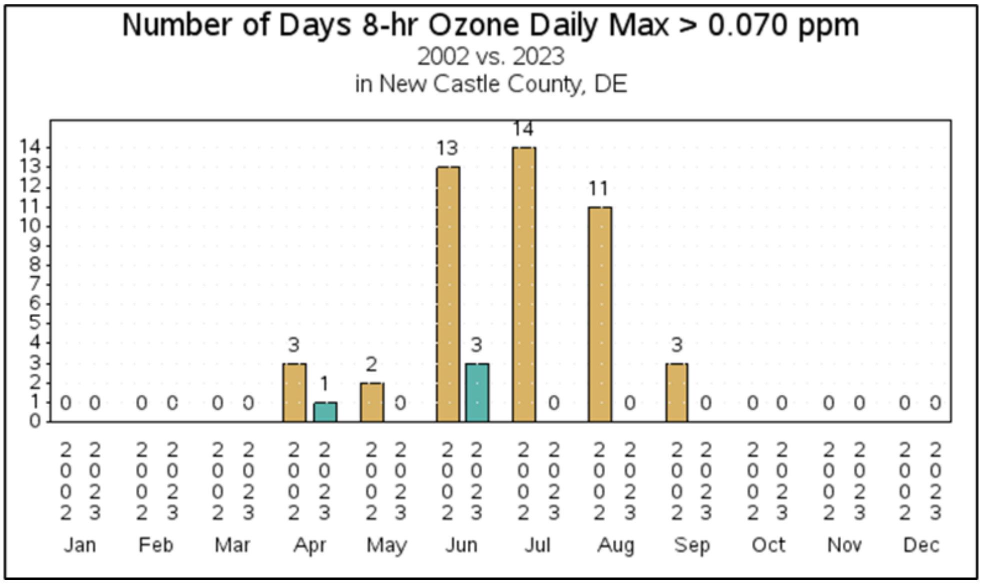
Note. Created by staff using data downloaded from EPA, 2024, February 28, Air Pollutant Emissions Trends Data, https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

NAAQS Exceedance Days

Over the past two decades, Delaware has significantly reduced the amounts of ozone precursor emissions. Although there are still occasional days where the ozone NAAQS is exceeded, it is important to acknowledge that the the level of the ozone NAAQS has decreased. In 2000, the ozone NAAQS was 0.080 ppm. The most recent change to the ozone NAAQS occurred in 2015, when it was lowered to 0.070 ppm. In recent years, Delaware has seen a positive change in the number of days per year that the ozone NAAQS was exceeded. Figure 24 shows that in 2002, there were a total of 46 days where the 8-hour ozone daily max was greater than 0.070 ppm in New Castle County; while in 2023, there were only four days that exceeded the NAAQS (EPA, 2024b).

Figure 24

The number of days where the 8-hour ozone NAAQS of 0.070 ppm was exceeded in New Castle County declined in 2023 compared to 2002.



Note. From EPA, 2024, June 27, Air Data - Ozone Exceedances, https://www.epa.gov/outdoor-air-quality-data/air-data-ozone-exceedances

Section Six: Delaware and the NAAQS

Designations and Classification

As we discussed previously, there are six criteria pollutants that act as indicators of air quality in this country. The NAAQS are the concentrations of these pollutants, above which, adverse effects on human health or public welfare may occur. After EPA sets a new standard, or revises an existing standard for a pollutant, the CAA requires EPA to determine which areas in the country meet the new standards.

When a new or revised standard is introduced, states submit recommendations to the EPA on whether or not an area is attaining the NAAQS for the pollutant. These recommendations are based on air quality data collected from monitors at locations in urban and rural settings as well as other information characterizing air quality such as modeling. The EPA reviews the recommendations and then designates an area as attainment or nonattainment for the standard.

If the air quality in a geographic area meets or is cleaner than the national standard, it is called an attainment area (classified as attainment/unclassifiable). This category includes areas for which EPA has determined there is sufficient evidence to find they are attaining or are likely to be attaining the NAAQS and are not contributing to a nearby violation. Areas that do not meet the national standard are called nonattainment areas. EPA reserves a separate unclassifiable category for areas where it can't determine, based on available information, whether the areas

are meeting or not meeting the NAAQS, and the EPA has not determined that the areas contribute to a nearby violation (EPA, 2024m).
For initial designations, areas that are designated as nonattainment are then further classified based on the severity of their pollution levels. This is based on the area's "design value" (DV) which, for ozone, represents the air quality in the area for the most recent three years. The possible classifications are, in ascending order of severity:

- Marginal
- Moderate
- Serious
- Severe
- Extreme

At the time of initial designations, nonattainment areas with a "lower" classification have pollutant levels that are closer to the standard than areas with a "higher" classification. Accordingly, areas in the lower classification levels have fewer and/or less stringent mandatory air quality planning and control requirements than those in higher classifications. Each attainment classification is given a deadline to attain the NAAQS. The "higher" classifications have more time. When an area is given a designation that area must attain by the specified date. If that does not happen, the area will be "bumped up" to the next classification. This provides more time to attain the NAAQS and requires additional action of the nonattainment area ("Additional Air Quality Designations," 2018). Once designations take effect, state and local governments must develop implementation plans outlining how areas will attain and maintain the standards by reducing air pollutant emissions.

In 2012, the EPA revised the annual primary standard for $PM_{2.5}$ from 15 micrograms per cubic meter ($\mu g/m^3$) to 12 $\mu g/m^3$. Following the standard revision, Delaware submitted a recommendation in the fall of 2013 that each of its three counties should be considered to be in attainment with this standard (DNREC, 2013). Following its review, EPA reached the same conclusion and designated all three counties as attainment in September 2014. (EPA, 2024f)

On February 7, 2024, EPA revised the annual primary standard for $PM_{2.5}$ from 12 $\mu g/m^3$ to 9.0 $\mu g/m^3$ to provide increased public health protection, consistent with the available health science. This rule change also included changes to the AQI to reflect the revised $PM_{2.5}$ standard (DNREC, 2015). Delaware has not yet been officially designated as in attainment with the new standard, but our monitors showed that $PM_{2.5}$ emissions averaged less than 9.0 $\mu g/m^3$ in 2021-2023.

Delaware's Attainment Status

We know that Delaware is in attainment with the 2012 annual primary $PM_{2.5}$ standard, but what about the other standards? Delaware is currently designated as in attainment with all NAAQS, with the exception of New Castle County, which is considered nonattainment for ozone. Attainment of the ozone standard has been a challenge for Delaware since a standard was first established in 1971. Ozone levels in Delaware have reduced throughout the years, but so has the NAAQS.

In March 2008, EPA finalized a revision to the NAAQS for ground level ozone and revised the 8-hour "primary" ozone standard from 0.080 ppm to a level of 0.075 ppm. At this time, EPA also set the "secondary" 8-hour ozone standard to a level of 0.075 ppm (EPA, 2012). Based on these

standards, both New Castle and Sussex counties were designated as marginal non-attainment, and Kent County was designated as in attainment.
In its most recent action, on October 26, 2015, EPA again strengthened the ozone NAAQS. Both the primary and secondary ozone standards were reduced to 0.070 ppm. This time, both Kent and Sussex counties were designated as attainment while New Castle County remained designated as marginal non-attainment. In 2020, EPA reviewed the standard and decided to maintain the primary and secondary standards at the same 0.070 ppm level. Since EPA is required to review the standards on a regular basis, we may see this level change in the future (EPA, 2023b, 2024q).

New Castle County's nonattainment status is tied to the Philadelphia Area which includes counties from Delaware, Maryland, New Jersey and Pennsylvania. The region was required to reduce ozone below the 0.070 ppm standard by August 3, 2021. Unfortunately, this standard was not reached by the deadline, so the region was bumped-up from a marginal to moderate nonattainment area. As a moderate nonattainment area, the state air agencies were required to submit SIP revisions and implement controls to satisfy the statutory and regulatory requirements for moderate nonattainment areas. The new deadline to reduce ozone below 0.070 ppm was August 3, 2024. Again, the area did not meet the standard and was recently bumped-up again from a moderate to a serious nonattainment area on July 30, 2024. It should be noted that the monitors in New Castle County are meeting the standard, but there are multiple monitors in the Philadelphia Nonattainment Area that are not. The entire nonattainment area must now attain the 2015 ozone NAAQS by the attainment date of August 3, 2027, or it will be bumped up once more to the severe classification (DNREC, 2023, pp. 16-19).

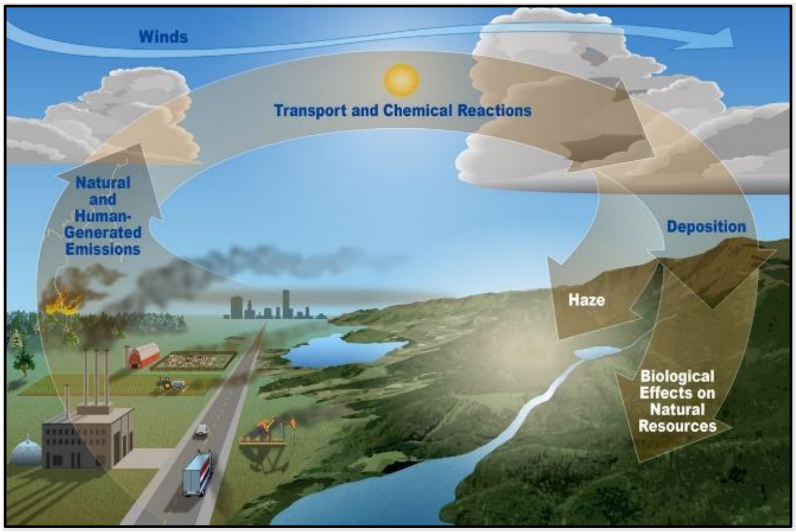
Delaware's Neighbor Nuisance

Over the last twenty years, Delaware has adopted and implemented SIP provisions that cover VOC and NO_X emitting sources and source categories. With these provisions in place, emissions of ozone precursors are well controlled in Delaware. Then why hasn't Delaware's air quality improved further? To answer that question, we must look outside of Delaware because the total pollution in any area comes from the combination of local and upwind sources.

Air pollution transport refers to pollution from upwind emission sources that impact air quality in a downwind location (EPA, 2024e). Transported pollutants are generally emitted from sources with large stacks, like power plants, which release the pollutants high into the air and cause them to travel great distances and affect air quality and public health regionally (see Figure 25). Emissions of some pollutants, like SO_2 and NO_X, from upwind sources can undergo chemical reactions in the atmosphere to form fine particle pollution that settles in a downwind state. Similarly, NO_X emissions can react in the atmosphere to create ground-level ozone.

Figure 25

Wind can move air pollutants short or very long distances before they cause harmful impacts



Note. From National Park Service, 2018, January 17, Where does air pollution come from?, https://www.nps.gov/subjects/air/sources.htm

The direction and speed of wind determines where and how far pollutants will travel. In the United States, air currents tend to sweep from west to east. That means that pollution from the Midwest often ends up in states along the Eastern coast (Cummins, 2018). The transport of these pollutants across state borders, referred to as interstate air pollution transport, can make it difficult for downwind states to meet health-based air quality standards, NAAQS, for $PM_{2.5}$ and ozone.

As you probably guessed, Delaware is considered a downwind state. In fact, Delaware is located in what is termed "the Ozone Transport Region" (OTR). The OTR was established by Congress in 1990 in order to address air pollution in downwind states that is caused by activity in upwind states. The OTR is essentially a single, 13-state ozone nonattainment area. The member states of the OTR are Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, parts of Virginia, and the District of Columbia ("Ozone Transport Commission," 2020).

While we still have local sources of air pollution, air quality modeling demonstrated that a large percentage of the contaminants in our air originate from upwind states. As we discussed earlier in this guide, the CAA addresses pollution that travels from state to state in what's referred to as the "Good Neighbor Provision." Further improvements in Delaware's air quality will depend on the reduction of upwind and mobile source emissions.

DNREC remains committed to continue finding ways to improve Delaware's air quality, including solutions both within and outside of state borders (Eichmann, 2018).

Section Seven: Relating Air Quality to the 2025 Current Issue (Roots and Resiliency - Fostering Forest Stewardship in a Canopy of Change)

Forest stewardship requires us to examine current forest practices, identify vulnerabilities, and identify necessary adaptations. To create viable solutions for future resilient forests, one will have to examine traditional ways and knowledge of stewardship, as well as scientific innovations and techniques.

We are at a defining moment for the world's forests. Without healthy and resilient forests, we will lose the fight against climate change and against the alarming loss of biodiversity. Extraordinary forest fire events are occurring all over the world. We know that forest stewardship, including sound efforts towards protection, conservation, and restoration as well as active management for forest products and services, can be an important factor in addressing these challenges by making forests more resilient. This approach can be informed by both indigenous knowledge and western science, enabling forests to adapt to changing conditions and increase their resilience and function.

Role of Forests on Air Quality

Urban forests play an important role in the environment. Urban forests moderate local climate by slowing wind and storm water, reducing energy use by providing shade in the summer and wind breaks in the winter, remediating soils, and providing animal and plant habitat, in addition to improving recreational areas for people (National Urban and Community Forestry Advisory Council, 2015).

The environmental effects of urban forestry may be summed up using the following acronym:

T: Temperature reduction
R: Remove air pollutants
E: Emission of VOCs
E: Energy effects (on buildings) (Nowak, n.d.)

Tree transpiration and canopies affect air temperature, radiation absorption and heat storage, wind speed, relative humidity, turbulence, and mixing-layer height. All of these attributes effect the movement of air pollution and consequently the concentration of air pollution in urban areas. Reduced air temperature due to trees improve air quality because the emission of many pollutants and/or ozone forming chemicals are temperature dependent.

Trees remove pollution through absorption and adsorption of gaseous airborne pollutants while larger particles may settle temporarily on tree surfaces. Studies show that large healthy trees will remove exponentially more air pollution than small healthy trees.

Trees do emit some VOCs, which can contribute to formation of ozone, and CO, however, ozone formation is counteracted by the cooling nature of forests. Additionally, rates of VOC emissions vary by plant species, good forest stewardship includes consideration of tree types based on location.

Energy effects on buildings can be helpful or harmful, depending upon how and where trees are planted; providing shade from the sun is useful in the summer but unhelpful in the winter, while blocking a cold wind is useful in the winter, but blocking a cooling breeze is unhelpful in the summer. Since building heating and cooling is achieved using fossils fuels, reduction in energy use translates to lower fossil fuel use.

Increasing the tree canopy in cities is one way to fight both poor air quality and urban heat islands (American Society of Landscape Architects, n.d.). An urban heat island is a metropolitan area that's a lot warmer than the rural areas surrounding it. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. These pockets of heat are referred to as "heat islands" (EPA, 2024s). Research shows significant short-term improvements in air quality in urban areas with 100 percent tree cover. There, trees can reduce hourly ozone by up to 15%, SO_2 by 14 percent, and PM by 13 percent. Furthermore, a single large healthy tree can remove greater than 300 pounds of carbon dioxide from the atmosphere every year (American Society of Landscape Architects, 2011).

Role of Forests on Climate Change

Planting trees and preventing deforestation are key measures in reducing the human impact of global climate change. Trees lessen the force of storms and reduce the amount of runoff into sewers, streams and rivers, improving water quality and reducing flooding (Kim, 2021). According to researchers, the key lies in being strategic about the types of trees planted and their locations to get the maximum air quality benefit from planting new trees. Because of the large number of species on Earth, it is impractical to study each tree species' unique effects on carbon and nutrient cycling. Recently, there has been a push to classify trees into groups to help predict the consequences of tree species shifts (Indiana University, 2021).

China has done more afforestation and reforestation than the rest of the world combined. We can learn a lot from these large-scale tree-planting projects. In the dry northern part of the country, people have planted trees to fight desert expansion. But because the tree species that were planted were ill-suited to a dry climate, this effort has depleted water supplies and degraded soils. In the south of China, reforestation with monocultures—that is, just one species of tree—has led to loss of biodiversity (Melillo, n.d).

Natural regeneration of forests has few unintended consequences and large potential to store carbon over the coming decades. If done worldwide, natural regeneration of forests could capture up to 70 billion tons of carbon in plants and soils between now and 2050—an amount equal to around seven years of current industrial emissions. Combining natural regeneration with thoughtful afforestation and reforestation is an important option for combating climate change (Melillo, n.d.).

Delaware Forests

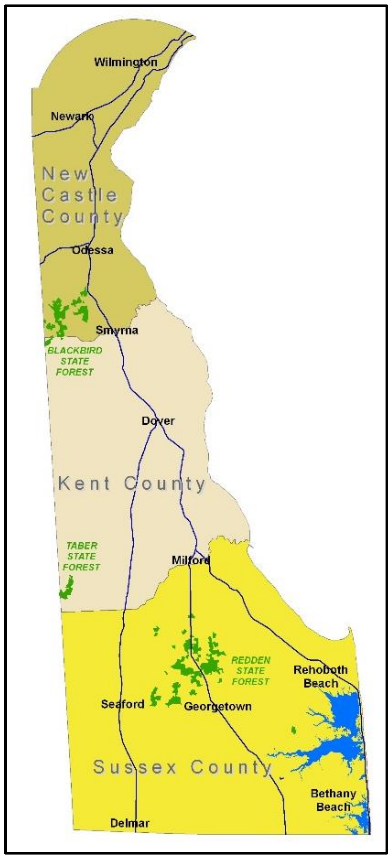
Climate change is affecting Delaware and will continue to influence our state going forward. From increased temperatures and rising sea levels to heavy precipitation and flooding, our residents are experiencing the impacts of climate change in their daily lives. Acting on climate change is necessary to protect the people, places, and resources we love in Delaware. For more than a decade, Delaware has taken steps to address the causes and consequences of climate change. But we need to do more (De Mooy et al., 2021).

Delaware has an estimated 353,435 acres of forested land (Hoyd et al., 2024). Urban areas are often more vulnerable to extreme heat waves than rural areas, due to the way that materials such as concrete and asphalt absorb and retain heat during the day, as well as the lack of trees to provide shade and cooling.

The Delaware Forest Service manages three state forests, shown in Figure 26, totaling more than 20,000 acres: Blackbird Forest near Smyrna, Taber Forest near Harrington, and Redden Forest near Georgetown.

Figure 26

Map of Delaware's three state forests



Note. From Delaware Department of Agriculture, n.d., Delaware State Forests, https://agriculture.delaware.gov/forest-service/state-forests/

In addition to this, the Delaware Forest Service's Stewardship Program provides private landowners with opportunities to improve the quality of their forested land through professional technical and education assistance (DelTrees, 2021).

In 2021, Governor John Carney, with the help of Delaware Dept. of Agriculture Secretary Michael Scuse and former DNREC Secretary Shawn Garvin (see Figure 27), launched the Tree for Every Delawarean Initiative (TEDI) with a goal of planting one million trees in the state by 2030.

Residents can follow the state's progress on its TEDI goal, and even upload information about where they've planted trees, at https://dnrec.delaware.gov/tedi/. The site also offers tips on what types of trees grow best in the area and how to plant and care for the trees as they grow.

Figure 27

Picture from the launch of the TEDI tree planting in 2021

Note. 27 From DelTrees, 2021, December 13, "Tree for Every Delawarean Initiative," Delaware Trees. https://delawaretrees.com/first-state-launches-tree-for-every-delawarean-initiative-tedi/

DNREC also developed a pilot riparian forest buffer cost share program in the Chesapeake Bay watershed, with hopes to eventually offer the program statewide.

As the State of Delaware struggles to comply with ever-lower air quality standards, the ways that trees can help to clean the air should not be overlooked. Trees are an important, localized, on-site, cost-effective solution to reducing pollution and improving air quality when planned, implemented, and maintained properly.

* * * * * * * * * * * *

Delaware 2025 Envirothon, Air Quality Student Guide
"Checking the Air Because We Care"

References

Additional Air Quality Designations for the 2015 Ozone National Ambient Air Quality Standards. 83 F.R. 25776 (final June 4, 2018) (to be codified at 40 C.F.R. § 81). https://www.govinfo.gov/content/pkg/FR-2018-06-04/pdf/2018-11838.pdf

AirNow. (n.d.). U.S. Environmental Protection Agency AirNow *Using Air Quality index*. https://www.airnow.gov/aqi/aqi-basics/using-air-quality-index/

Ambient Air Quality Surveillance, 40 C.F.R. § 58.1 (2024). https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-58/subpart-A/section-58.1

American Society of Landscape Architects. (n.d.) *Designing Our Future: Sustainable Landscapes*. (n.d.). https://www.asla.org/sustainablelandscapes/Vid_UrbanForests.html#:~:text=Increasing%20the%20tree%20canopy%20in%20cities%20is%20one,14%20percent%2C%20and%20particulate%20matter%20by%2013%20percent

American Society of Landscape Architects. (2011, October 6). *Growing Urban Forests: The Secret to Cleaner, Cooler, City Air*. Planet Forward. https://planetforward.org/story/growing-urban-forests-the-secret-to-cleaner-cooler-city-air/

Beamish, J. J., Irwin, S. T., & Zahn, P. H. (2024, April 19). *State of Delaware Final Report: Ozone and $PM_{2.5}$ Observations and Forecasts in 2023*. Delaware Department of Natural Resources and Environmental Control. https://documents.dnrec.delaware.gov/Air/ozone-reports/DE-Ozone-PM-2023.pdf

California Air Resources Board. (n.d.-a). *Inhalable Particulate Matter and Health ($PM_{2.5}$ and PM_{10})*. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health#:~:text=Particles%20are%20defined%20by%20their,5)

California Air Resources Board. (n.d.-b). *National Ambient Air Quality Standards*. https://ww2.arb.ca.gov/resources/national-ambient-air-quality-standards

California Air Resources Board. (n.d.-c). *Ozone & Health*. https://ww2.arb.ca.gov/resources/ozone-and-health

Canadian Lung Association. (n.d.). *Breathing*. https://www.lung.ca/lung-health/lung-info/breathing

Center for Science Education. (n.d.). *Volatile Organic Compounds (VOCs)*. University Corporation for Atmospheric Research Center for Science Education. https://scied.ucar.edu/learning-zone/air-quality/volatile-organic-compounds

Cummins, E. (2018, February 6). *Find out where your town's air pollution actually comes from*. Popular Science. https://www.popsci.com/air-pollution-cross-border

De Mooy, J., Pletta, M., & Yue, I. (2021, November). *Delaware's Climate Action Plan*. Delaware Department of Natural Resources and Environmental Control. https://documents.dnrec.delaware.gov/energy/Documents/Climate/Plan/Delaware-Climate-Action-Plan-2021.pdf

Delaware Department of Natural Resources and Environmental Control. (n.d.) *Moveable Monitoring Platform.* https://dnrec.delaware.gov/air/quality/monitoring/mmp/

Delaware Department of Natural Resources and Environmental Control. (2013, November 21). Technical Support Document to Support a Designation of Attainment of the 2012 Fine Particle ($PM_{2.5}$)

NAAQS. U.S. Environmental Protection Agency. https://www3.epa.gov/airquality/particlepollution/designations/2012standards/rec/r3derec1.pdf

Delaware Department of Natural Resources and Environmental Control. (2015, September 2). *Delaware Particulate Matter (PM) Advance Program – Path Forward Plan*. https://documents.dnrec.delaware.gov/Air/Documents/PM%20Advance/Path%20Forward%20Plan.pdf

Delaware Department of Natural Resources and Environmental Control. (2021, June 23). *Eden Park Air Monitoring Study: Public Meeting Discussion*. https://documents.dnrec.delaware.gov/Air/monitoring/mamap/Eden-Park-Air-Monitoring-Study-Presentation.pdf

Delaware Department of Natural Resources and Environmental Control. (2023, November 28). *Final Proposal, Delaware State Implementation Plan – Moderate Non-attainment Plan for New Castle County for the 2015 8-Hour Ozone National Ambient Air Quality Standard*. https://documents.dnrec.delaware.gov/Admin/Hearings/2023-R-A-0016-0017/exhibits/0016/Final-Attainment-Plan.pdf

Delaware Department of Natural Resources and Environmental Control. (2024, May). *Delaware Ambient Air Network Monitoring Plan for Criteria Pollutants*. https://documents.dnrec.delaware.gov/Air/monitoring/delaware-air-monitoring-network-plan.pdf

DelTrees. (2021, December 13). *"Tree for Every Delawarean Initiative" (TEDI)*. Delaware Trees. https://delawaretrees.com/first-state-launches-tree-for-every-delawarean-initiative-tedi/

Eichmann, M. (2018, July 16*). Delaware protests EPA decision on air pollution*. WHYY. https://whyy.org/articles/delaware-protests-epa-decision-on-air-pollution/

Hoyd, K., Delaware Forest Service, National Association of Conservation Districts, & Lueckel, B. (2024). *Delaware Forest Resource Fact Sheet 2024* https://apps.fs.usda.gov/nicportal/temppdf/sfs/naweb/de_brief.pdf

Indiana University. (2021, January 29). *Scientists look to soils to learn how forests affect air quality, climate change.* Phys.org. https://phys.org/news/2021-01-scientists-soils-forests-affect-air.html

Institute of Arctic and Alpine Research. (n.d.). *Trees and VOCs: Measuring volatile organic compounds from urban forests*. University of Colorado Institute of Arctic and Alpine Research. https://instaar.colorado.edu/outreach/trees-and-VOC/documents/TreesandVOC-posterforCreekside-2009-06-25.pdf

Kim, D. (2021, November 3). *Afforestation can help to tackle climate change. Here's how*. World Economic Forum. https://www.weforum.org/stories/2021/11/afforestation-can-help-tackle-climate-change-heres-how/

Melillo, J. (n.d.). *Forests and Climate Change*. MIT Climate Portal. https://climate.mit.edu/explainers/forests-and-climate-change

National Park Service. (2018b, November 5). *Ozone effects on tree growth*. U.S. Department of the Interior, National Parks Service. https://www.nps.gov/subjects/air/nature-trees.htm

National Urban and Community Forestry Advisory Council. (2015). *Ten-Year Forestry Action Plan: 2016-2026*. https://urbanforestplan.org/wp-content/uploads/2015/11/FinalActionPlan_Complete_11_17_15.pdf

Nowak, D. J. (n.d.). *THE EFFECTS OF URBAN TREES ON AIR QUALITY.* https://treediseases.cfans.umn.edu/sites/treediseases.cfans.umn.edu/files/2021-06/effects_of_urban_trees_on_air_quality.pdf

Ozone Transport Commission: Recommendation That EPA Require Daily Limits for Emissions of Nitrogen Oxides from Certain Sources in Pennsylvania. 85 F.R. 41972 (notice of availability July 13, 2020). https://www.govinfo.gov/content/pkg/FR-2020-07-13/pdf/2020-15005.pdf

U.S. Environmental Protection Agency. (n.d.-a). *How is the NowCast algorithm used to report current air quality?* https://usepa.servicenowservices.com/airnow/en/how-is-the-nowcast-algorithm-used-to-report-current-air-quality?id=kb_article&sys_id=bb8b65ef1b06bc10028420eae54bcb98

U.S. Environmental Protection Agency. (n.d.-b). *Our Nation's Air: Status and Trends Through 2023*. https://gispub.epa.gov/air/trendsreport/2024/#home

U.S. Environmental Protection Agency. (n.d.-c). *Our Nation's Air: Status and Trends Through 2023*. https://gispub.epa.gov/air/trendsreport/2024/#naaqs_trends

U.S. Environmental Protection Agency. (2012). *Final Rule to Implement the 1997 8-Hour Ozone National Ambient Air Quality Standard: Classification of Areas That Were Initially Classified as Subpart 1; Revision of the Anti-Backsliding Provisions to Address 1-Hour Contingency Measure Requirements; Deletion of Obsolete 1-Hour Ozone Standard Provision*. https://www.epa.gov/sites/default/files/2015-09/documents/2010-0885_factsheet.pdf

U.S. Environmental Protection Agency. (2018). *Volatile Organic Compounds Emissions*. https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=23

U.S. Environmental Protection Agency. (2023a, December 13). *About Air Quality Implementation Plans*. https://www.epa.gov/air-quality-implementation-plans/about-air-quality-implementation-plans#what-is-a-sip

U.S. Environmental Protection Agency. (2023b, August 21). *EPA Initiates New Review of the Ozone National Ambient Air Quality Standards to Reflect the Latest Science.* https://www.epa.gov/newsreleases/epa-initiates-new-review-ozone-national-ambient-air-quality-standards-reflect-latest

U.S. Environmental Protection Agency. (2024a, November 7). *Air Data - Multiyear Tile Plot*. https://www.epa.gov/outdoor-air-quality-data/air-data-multiyear-tile-plot

U.S. Environmental Protection Agency. (2024b, June 27). *Air Data – Ozone Exceedances*. https://www.epa.gov/outdoor-air-quality-data/air-data-ozone-exceedances

U. S. Environmental Protection Agency. (2024c, February 28). Air Pollutant Emissions Trends Data. https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

U.S. Environmental Protection Agency. (2024d, October 22). *Criteria Air Pollutants*. https://www.epa.gov/criteria-air-pollutants

U.S. Environmental Protection Agency. (2024e, October 22). *Cross-State Air Pollution*. https://www.epa.gov/Cross-State-Air-Pollution/cross-state-air-pollution

U.S. Environmental Protection Agency. (2024f). *Final Updates to the Air Quality Index (AQI) for Particulate Matter Fact Sheet and Common Questions*. https://www.epa.gov/system/files/documents/2024-02/pm-naaqs-air-quality-index-fact-sheet.pdf

U.S. Environmental Protection Agency. (2024g, May 16). *Health Effects of Ozone in the General Population*. https://www.epa.gov/ozone-pollution-and-your-patients-health/health-effects-ozone-general-population

U.S. Environmental Protection Agency. (2024h, April 9). *Health Effects of Ozone Pollution*. https://www.epa.gov/ozone-pollution/health-effects-ozone-pollution

U.S. Environmental Protection Agency. (2024i, November 20). *How to Use Air Sensors: Air Sensor Guidebook*. https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

U.S. Environmental Protection Agency. (2024j, January 22). *Managing Air Quality – Ambient Air Quality*. https://www.epa.gov/air-quality-management-process/managing-air-quality-ambient-air-monitoring

U.S. Environmental Protection Agency. (2024k, May 6). *National Emissions Inventory (NEI)*. https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

U.S. Environmental Protection Agency. (2024l, November 20). *Photochemical Assessment Monitoring Stations (PAMS)*. https://www.epa.gov/amtic/photochemical-assessment-monitoring-stations-pams

U.S. Environmental Protection Agency. (2024m, November 12). *Process to Determine Whether Areas Meet the NAAQS (Designations Process)*. https://www.epa.gov/criteria-air-pollutants/naaqs-designations-process

U.S. Environmental Protection Agency. (2024n, July 31). *Summary of the Clean Air Act*. https://www.epa.gov/laws-regulations/summary-clean-air-act

U.S. Environmental Protection Agency. (2024o, May). *Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI)*. https://document.airnow.gov/technical-assistance-document-for-the-reporting-of-daily-air-quailty.pdf

U.S. Environmental Protection Agency. (2024p, February) *Technical Documentation for the Framework for Evaluating Damages and Impacts (FrEDI).* https://www.epa.gov/system/files/documents/2024-02/technical-documentation-for-fredi_feb2024_0.pdf

U.S. Environmental Protection Agency. (2024q, September 25). *Timeline of Ozone National Ambient Air Quality Standards (NAAQS)*. https://www.epa.gov/ground-level-ozone-pollution/timeline-ozone-national-ambient-air-quality-standards-naaqs

U.S. Environmental Protection Agency. (2024r, November 21). *What are Hazardous Air Pollutants?* https://www.epa.gov/haps/what-are-hazardous-air-pollutants

U.S. Environmental Protection Agency. (2024s, December 10). *What Are Heat Islands?* https://www.epa.gov/heatislands/what-are-heat-islands#_ftnref1

U.S. Environmental Protection Agency. (2024t, September 30). *What Does the Clean Air Act Say about Cross-State Air Pollution?*. https://www.epa.gov/Cross-State-Air-Pollution/what-does-clean-air-act-say-about-cross-state-air-pollution#what-does-the-clean-air-act-say

U.S. Environmental Protection Agency. (2024u, September 30). *What is Cross-State Air Pollution?* https://www.epa.gov/Cross-State-Air-Pollution/what-cross-state-air-pollution

ACRONYM	FULL DESCRIPTION
AQ	Division of Air Quality
AQI	Air Quality Index
CAA	Clean Air Act
CAP(s)	Criteria Air Pollutant(s)
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CSN	Chemical Speciation Network
DNREC	Delaware Department of Natural Resources and Environmental Control
DV	Design Value
EPA	Environmental Protection Agency
FIP	Federal Implementation Plan
HAP(s)	Hazardous Air Pollutant(s)
MMP	Mobile Monitoring Platform
NAAQS	National Ambient Air Quality Standards
NCORE	National Core
NEI	National Emissions Inventory
NFEI	National Fire Emissions Inventory
NM	Nanometers
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides or Oxides of Nitrogen
OTR	Ozone Transport Region
PAMS	Photochemical Assessment Monitoring Stations
Pb	Lead
PM	Particulate Matter
PPB	Parts Per Billion
PPM	Parts Per Million
QA	Quality Assurance
SIP	State Improvement Plan
SLAMS	State and Local Air Monitoring Stations
SO_2	Sulfur Dioxide
TEDI	Tree for Every Delawarean Initiative
TSP	Total Suspended Particulates (also called “dust”)
UV	Ultra Violet
VOC(s)	Volatile Organic Compound(s)
WLF	Wild Land Fires