Ozone

Background

Ozone found in the lower atmosphere, or ground-level ozone, is created by chemical reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight and warm temperatures.

High concentrations of ground-level ozone are harmful to human health and the environment. The impacts on human health range from eye irritation to severe respiratory distress that can lead to chronic illness and premature death. Ground-level ozone lowers resistance to diseases such as colds and pneumonia. It also damages lung tissue, intensifies heart and lung diseases such as asthma, and causes coughing and throat irritation. Children and people with asthma are most at risk[1] although even healthy adults doing heavy exercise or manual labor outdoors may experience the unhealthy effects of ozone.

High ozone concentrations have a deleterious effect on the environment, particularly plant life, resulting in crop and forestry losses. In addition, ozone has the ability to break down the basic components of everyday products that we rely on for shelter, mobility and aesthetics. High ozone produces cracks in rubber and damages exterior paint on buildings, motor vehicles and boats. The effects of ozone result from it being a strong oxidant. Ozone is especially reactive with certain molecules, including those found in rubber, the photosynthetic apparatus of green plants, and the membranes lining the lung's air passages. [2]

New Jersey ground-level ozone formation is mainly a daytime problem during the summer months because it is greatly enhanced by warm temperatures and abundant sunlight. The ozone season currently runs from March 1 to October 31 with the highest or "peak" ozone concentrations usually occurring between 2 p.m. and 8 p.m. from June 1st through August 31st. Weather patterns have a significant effect on ozone formation, and hot, dry summers will result in higher ozone concentrations than cool, wet ones.

The primary pollutants that contribute to ozone formation are nitrogen oxides (NO_x) and volatile organic compounds (VOCs). "Nitrogen oxides" is a generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Some nitrogen oxides form naturally. The primary sources of human-made NO_x emissions in New Jersey are motor vehicles, construction equipment, power plants and industrial, commercial, and residential fuel combustion.

Volatile organic compounds are substances which contain carbon that evaporate easily. Primary sources of human-made VOC emissions are consumer products, such as household cleaners, paints and solvents, motor vehicles, lawn and garden equipment and gasoline stations. VOCs emitted from trees and other plant life also contribute to the creation of ozone in some regions.

Air quality is affected by both local emissions of ozone precursors and by pollution transported into the area by the wind. Transported pollution has a serious impact on New Jersey's air quality just as pollution from New Jersey affects areas downwind of it. As a result, controlling ozone pollution requires a broad range of measures to reduce sources of precursors both in New Jersey and in upwind regions. New Jersey's ozone control efforts have involved discussions with many states covering most of the eastern half of the country.

(Getty Images, 2021)

Goals

National Ambient Air Quality Standards (NAAQS) for ground-level ozone were first established in 1979 (a standard for total photochemical oxidants was previously established in 1971). These national health standards were revised in 1997 from a maximum 1-hour concentration of 0.12 parts per million (ppm) to a maximum 8-hour concentration of 0.08 ppm. The standard was again changed, effective May 27, 2008, to a maximum 8-hour average concentration of 0.075 ppm (75 parts per billion (ppb)). On Oct. 1, 2015, the USEPA further strengthened the NAAQS for ground-level ozone to 0.070 ppm (70 ppb).

To show compliance with the standard, the three-year average of the annual fourth -highest daily maximum 8-hour average concentration measured at any site within an area (multi-state for New Jersey) must not exceed the standard.[3] This is known as the “design value”. New Jersey is part of two multi-state areas which are in nonattainment of the standard (nonattainment areas).

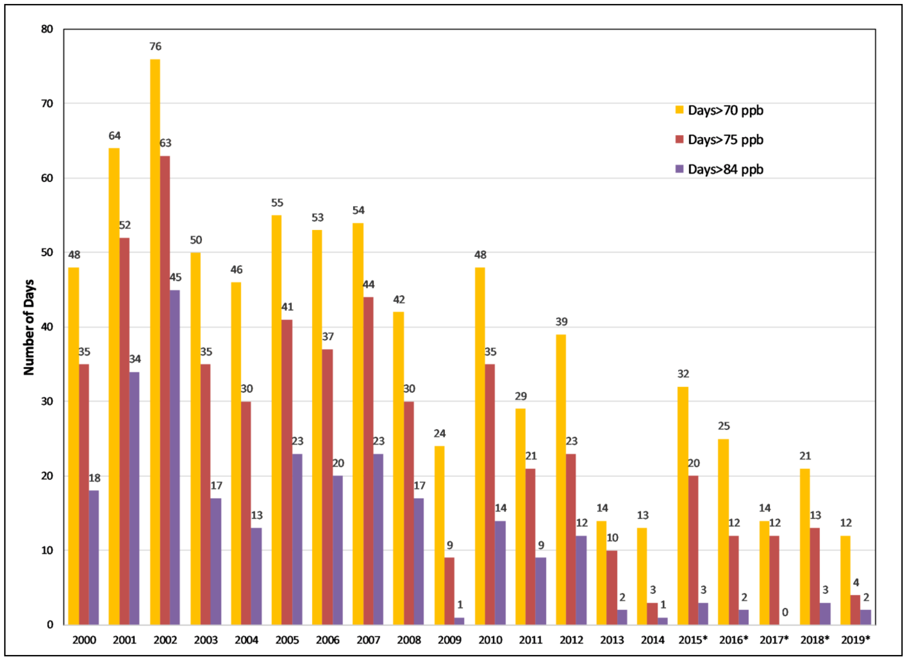

Figure 1: The number of exceedance days above the 8-hour ozone standards of 80 ppb, 75 ppb, and 70 ppb in New Jersey.

Status and Trends

One way to measure improvement in ozone air quality is by looking at the number of days ozone is above the health standard across the State. The New Jersey Department of Environmental Protection currently measures ozone concentrations at 16 sites in New Jersey. When one or more sites exceed the standard on a given day, it is counted as one ozone exceedance day. The trend in total days found above three different 8-hour ozone standards of 0.08 ppm, 0.075 ppm, and 0.070 ppm from 2000 through 2019 is shown in Figure 1. From 1997 to 2007, the NAAQS of 0.08 ppm was in effect, with attainment expressed as ≤84 ppb based on rounding conventions. From 2008 to 2015, the NAAQS of 0.075 ppm was in effect, and from 2016 through the present the NAAQS of 0.070 ppm has been in effect. As the standard continued to be lowered over time, NJ has established steady, if not decreasing, numbers of exceedances, although no statistically significant trend is evident at this time.

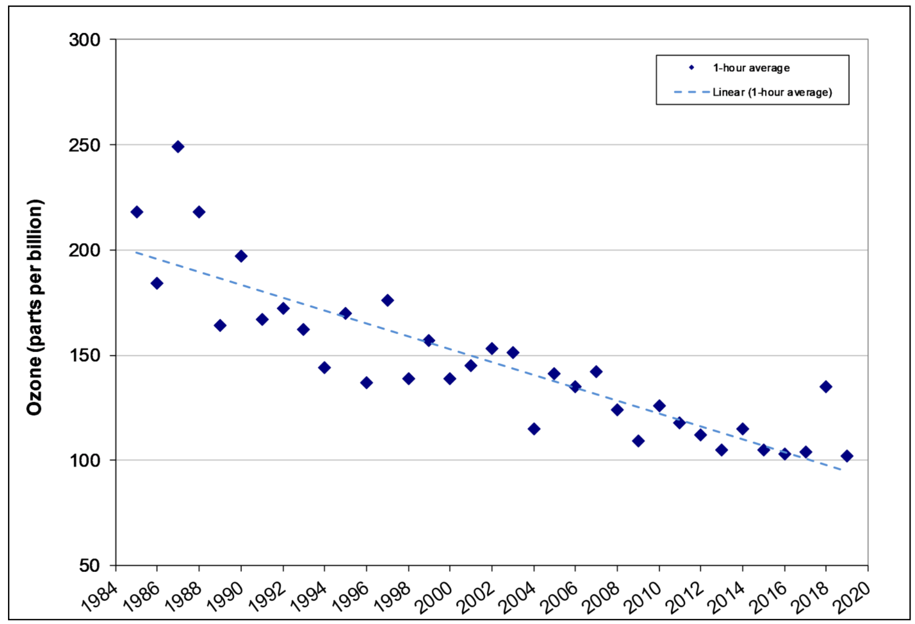

Figure 2: Maximum 1-Hour Ozone Concentrations occurring at any monitoring site in New Jersey

The annual maximum ozone concentrations occurring at any monitoring site in New Jersey for a given year are shown in Figure 2. The maximum value does not necessarily occur at the same site from year to year. Not all New Jersey monitoring sites ran continuously from 1985 to the present day. A decrease in the annual maximum ozone concentration, as measured over a 1-hour period, is evident over time. Trend analyses of these data indicate that the 1-hour average maximum ozone concentration shows a significant decline (p-value < 0.05) of approximately 53% from 1985 to 2019. In Figure 2, the 2018 data point stands out as higher than the maximum values for the previous 10 years. The statewide maximum 1-hour average for 2018 was 0.135 ppm, recorded at the Flemington site on July 2. Another site, Leonia, recorded a 1-hour daily maximum of 0.131 ppm on the same day. These high values were recorded during a regional high ozone event exacerbated by weather conditions including a large high pressure system over much of the U.S. eastern seaboard, abundant sunshine, and temperatures nearing 100°F.[4]

Design values or 3-year averages are the metrics that are compared to the NAAQS levels to determine compliance. The design value is based on the 4^{th} highest daily maximum 8-hour average concentration so that extreme values are not included in determining attainment of the NAAQS. Figure 3 shows a historical trend of the 4th highest daily maximum 8-hour average concentration along with the 8-hour ozone design values for New Jersey monitors. Similar to the maximum value data, the maximum design values are not necessarily measured at the same site from year to year and not all New Jersey monitoring sites ran continuously from 1985 to present day. This data also supports a decreasing trend in ozone concentrations. From the high of 0.116 ppm in 2002, the 3-year average shows a significant decline (p-value < 0.05) of approximately 36% by 2019 (0.074 ppm).

Trends in ground level ozone are influenced by many factors including emissions of NO_x and VOCs (ozone precursors), weather conditions, and emission reductions brought about by control measures. Short term fluctuations are most likely due to weather conditions. The long-term trend shows ozone concentrations decreasing significantly due to State and federal requirements to reduce emissions of NO_x and VOCs.

Figure 3: Design Values - 3 Year Average of 4th Highest Daily 8-Hour Maximum Ozone Concentration and 4^{th} Highest Daily 8-Hour Maximum Ozone Concentration (maximum values occurring at any site in New Jersey).

Initially in the 1980's and 1990's, reducing emissions of VOCs was the primary means of lowering concentrations of ground-level ozone in New Jersey. Several important VOC control measures were implemented in 1988 and 1989, including reductions in the volatility of gasoline, the installation of gasoline vapor recovery systems at gasoline stations (Stage I and II), and regulations to reduce the volatility of paints. Several other VOC regulations were implemented in the 1990's and 2000's such as new engine standards for motor vehicles and off-road equipment, consumer products, additional paint controls, autobody refinishing, solvent degreasing, gasoline cans, asphalt paving, storage tanks, fuel loading and unloading at marine terminals, and refinery controls.

NO_x was recognized as an important precursor to ozone in the Clean Air Act of 1990. State and federal NO_x controls that contribute to the decreasing ozone trend include regulations for new engine standards for motor vehicles and off-road equipment, National and State low-emission vehicle (LEV) programs, the NO_x Budget Trading Program (NBP) for power plants (1999 and 2003), New Jersey power plant and refinery controls (post 2002), New Jersey's high electric demand day and multi-pollutant power plant rules (post 2009).

Outlook and Implications

The State expects additional emission reductions of ozone precursors in the future due to existing State and federal controls that have been adopted. Emission reductions will continue to be realized as the controls are implemented and the fleet turns over. These controls include new engine standards for motor vehicle and off-road equipment, as well as statutory goals established in January 2020 for future adoption of plug-in battery-powered vehicles and plug-in electric hybrid vehicles under P.L. 2019 c.362. Among the goals, by December 31, 2025, the total number of registered light-duty plug-in electric vehicles (including battery-only and plug-in hybrids) should reach 330,000 units, and by the end of 2035 the number should reach two million. By the end of 2040, 85% of new light-duty vehicles sold in the state should be plug-in electrics.

In addition to the control measures discussed above, New Jersey has recently adopted VOC control measures to meet certain federal Control Technique Guidelines, and NOx control measures for the natural gas-fired engines/turbines at compressor stations. New Jersey's Protecting Against Climate Threats (NJ PACT) effort is focused on responding to current climate threats and reducing future climate damages. New Jersey's electric vehicle goals and NJ PACT will decrease of the use of fossil fuel combustion, which will also have the benefit of reducing emissions of ozone precursors.

Transported pollution has a serious impact on New Jersey's air quality just as pollution from New Jersey affects areas downwind of it. As a result, reductions in ozone in the future will require emission reductions in both NO_x and VOCs achieved over a large multi-state region, with a focus on high electric demand days and ozone episodes. Because most upwind states are regulating emissions on an annual basis, it does not address the short-term impacts of daily peak emissions, especially those from power plants operating during high electric demand days, which generally coincide with high temperature and high ozone levels. Therefore, maximum daily emission values are more valuable to assess the episodic occurrences of elevated ozone concentrations.

Even as the emissions of ozone precursors decrease, ground-level ozone is expected to increase in the future as a result of warming temperatures from climate change. In this phenomenon of ozone-climate penalty, air quality is projected to deteriorate simply due to warmer air (Fu and Tian 2019). Controlling anthropogenic sources of ozone pollution is especially important in our warming climate.

More Information

See the NJDEP Bureau of Air Monitoring Web site, http://www.njaqinow.net/Default.aspx, and the site developed by USEPA, NOAA, and other entities at http://airnow.gov.

References

[1]New Jersey Department of Environmental Protection. Bureau of Air Quality Planning. Ozone. Accessed Nov. 2014 at https://www.nj.gov/dep/baqp/ozone.html.

[2]Spiro, Thomas, and William Stigliani, 2003, *Chemistry of the Environment, 2nd Edition*, Prentice Hall, Upper Saddle River, NJ 07458, page 226.

[3]New Jersey Department of Environmental Protection. 2012 Air Quality Report: Ozone Summary. Accessed Nov. 2014 at https://www.njaqinow.net/App_Files/2012/Ozone2012.pdf

[4]New Jersey Department of Environmental Protection. Ozone National Ambient Air Quality Standard Health Exceedance on July 2, 2018. Accessed Oct. 2020 at https://www.nj.gov/dep/cleanairnj/exceedances/2018/070218.pdf

[5]Fu, T. M., and H. Tian. 2019. Climate change penalty to ozone air quality: Review of current understandings and knowledge gaps. Current Pollution Reports 5:159–171.