NOx and VOC Emission Trends: Ozone Precursors

Background

Ozone

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. 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.

Nitrogen oxides are the 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, industrial, commercial, and residential fuel combustion and commercial marine vessels. 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.

For more information on ozone formation, the effects of ozone to human health and the environment and ozone monitoring trends, please refer to the New Jersey Department of Environmental Protection (Department or NJDEP) Ozone Environmental Trends Report.

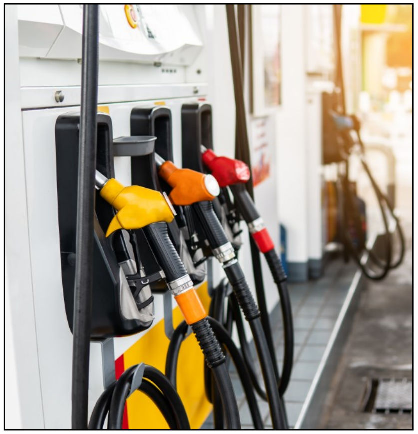
Emissions

New Jersey's emission inventories for ozone precursors NOx and VOC coincide with the peak ozone season (June 1st through August 31st) when "summer tons" per day are recorded. Annual emissions data do not provide the information needed to analyze the impacts of peak emissions on ozone, especially those from power plants operating during high electric demand days in the summer, which generally coincide with high temperature and high ozone levels. Therefore, maximum daily emission values during the peak ozone season are more valuable to assess the occurrences of elevated ozone concentrations.

The four major human-made emission source categories for ozone precursors NO_x and VOC are on-road mobile sources (e.g., cars, trucks and buses), non-road mobile sources (e.g., construction and farm equipment, trains, aircraft, marine vessels, recreational watercraft, lawn maintenance equipment), point sources (e.g., manufacturing and power industries and petroleum refining and storage) and area sources (e.g., paints, consumer products, heating fuel combustion, gasoline service stations, autobody refinishing facilities, small commercial and industrial sources, fires).

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 and is considered the primary precursor in more recent times. State and federal NO_x controls which 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).



(Getty Images, 2021)

Status and Trends

Figures 1 and 2 show historical New Jersey NOx and VOC emission trends for the peak ozone season (summer day) by emission source sector. As shown in Figures 1 and 2, in 2017, the largest categories of ozone precursor emissions were on-road mobile for NOx and area sources for VOCs in New Jersey. The on-road mobile source emissions contributed approximately 44 percent of the NO_x emissions and the area source emissions contributed approximately 55 percent of the VOC emissions.

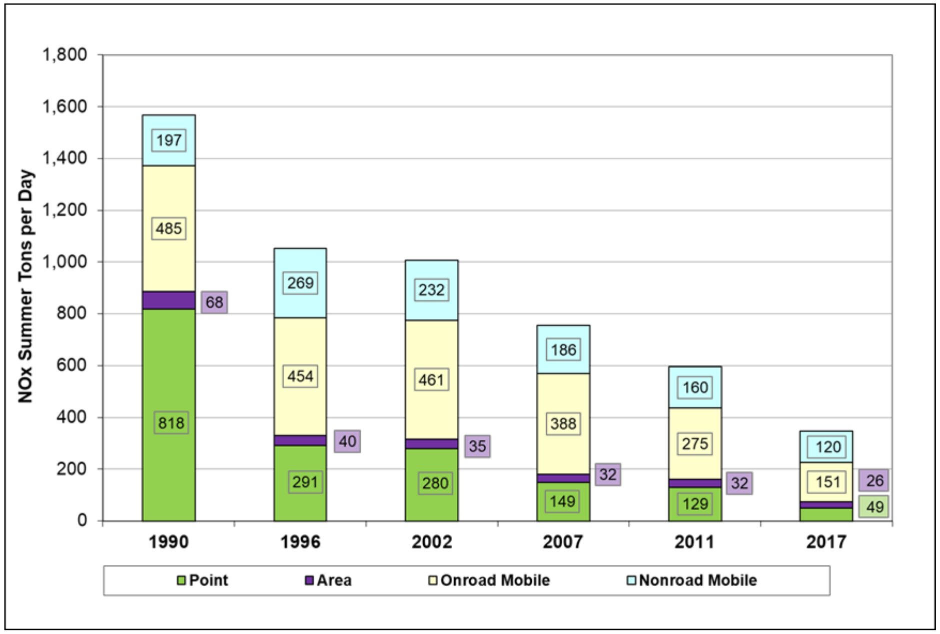


Figure 1. New Jersey Statewide Nitrogen Oxides (NO_x) Emission Trend.

Between 1990 and 2017, the emissions from the total of all four source categories were estimated to have decreased approximately 78 percent for NO_x and 69 percent for VOCs. Between 2011 and 2017, emissions are estimated to have decreased by approximately 42 percent for NO_x and 23 percent for VOCs.

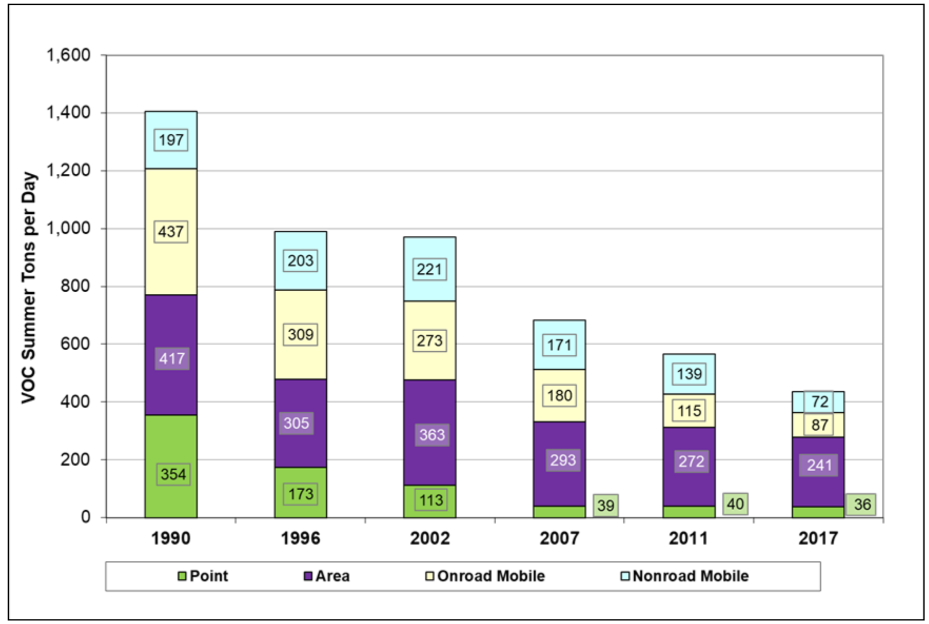


Figure 2. New Jersey Statewide Volatile Organic Compound (VOC) Emission Trend.

The NO_x decreases shown in Figure 1 were achieved in the on-road sector due to motor vehicle fleet turnover and the National and State low emission vehicle programs. Decreases in the point source sector were due primarily to the NO_x budget program for power plants, power plant and refinery consent decrees (enforcement agreements), and New Jersey's high electric demand day and multi-pollutant power plant rules. NO_x decreases were achieved in the non-road sector due to new engine standards for non-road vehicles and equipment.

The VOC decreases shown in Figure 2 were achieved in all sectors due to motor vehicle fleet turnover, federal new engine standards for on and off road vehicles and equipment, the National and State low emission vehicle programs, area source rules affecting such things as consumer products, portable fuel containers, paints, autobody refinishing, asphalt paving applications, solvent cleaning operations, and point source controls.

Emission trends estimates may be affected by calculation methodology changes. Various calculation methods and models have been used to estimate the emissions of VOCs and NO_x from New Jersey sources. These calculation methods and models are often modified over time with more accurate data or methods to better estimate VOC and NO_x emissions. These updates often increase emission estimates. Therefore, the overall decreasing emission trends shown in Figures 1 and 2 due to pollution controls and regulations are actually greater than shown and apparent increases in emissions in some source categories from 1996 to 2002, such as on-road mobile, are the result of methodology changes, not actual increases. The USEPA model used to calculate on-road mobile emissions has changed several times over the timeframe shown. Model changes resulted in increased emission estimates for VOC and NO_x from 1996 to 2002 and from 2002 to 2007. Other examples of methodology changes that significantly affected emission estimates were for residential wood burning, forest fires, and the addition of new area source categories that weren't previously in the inventory such as portable gasoline containers. The USEPA models used to calculate non-road equipment, aircraft emissions and commercial marine vessel emissions have also changed several times over the timeframe shown.

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 NJPACT 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

Division of Air Quality: https://www.nj.gov/dep/daq/

Air Monitoring: https://www.njaqinow.net/

Air Planning: https://www.nj.gov/dep/baqp/

References

[1]Environmental Trends Report, "Ozone" NJDEP, Office of Science, https://www.state.nj.us/dep/dsr/trends/.

[2]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.