Air Quality in the Meadowlands of New Jersey
September 2022-December 2023 Report
April, 2024

1. Introduction

The air quality in metropolitan New Jersey is a concern because of the high population density, multiple super-highways, three main U.S. airports, power plants, trash incinerators, and industry. Northern New Jersey has the city of Newark which is the largest city in the state with over 278,000 residents including 52% African American and 33% Hispanic/mixed, and where 28% of residents live below the poverty line (EPA, 2015a). The city of Newark is well known for its poor air quality as it is close to the Port of Newark, Newark International Airport, several energy generating stations, the NJ Turnpike, Route 1&9, one of the largest incinerators in the East Coast, one of the largest sewage treatment facilities in the east coast (Passaic Valley Sewerage Commission, PVSC). The meadowlands of New Jersey are located close to Newark City and New York City, and it is a reference air quality monitoring site for regional air quality control. There is also a need to acquire long-term monitoring of common air pollutants in the Meadowlands District where there is a high concentration of landfills and National Priority Listed Sites.

Moreover, in 2007, the state of New Jersey set a goal to reduce greenhouse gas emissions to 80% below 2006 levels by 2050 in Executive Order #54 (State of New Jersey, 2007). Globally, the CO_2 level in 2006 was about 380 ppm. The CO_2 level in 2020 reached 420 ppm. The Intergovernmental Panel on Climate Change (IPCC) indicates that an emission scenario that would lead to a CO_2 equivalent concentration equal to or lower than 450 ppm would likely maintain warming to below a 2 ºC increase relative to pre-industrial levels (IPCC, 2014). With the Regional Greenhouse Gas Initiative (RGGI), New Jersey's goal is to achieve 100% clean energy by 2050 by shifting to clean and renewable energy sources and reducing greenhouse gas emissions (RGGI, 2020). Therefore, it is necessary to monitor the greenhouse gas levels in the District long-term, to verify the effects of massively introducing clean and renewable energy and reducing fossil fuel consumption on local greenhouse gas emissions.

This study focuses mainly on the metropolitan area of northern New Jersey, and the goal was to monitor the long-term air quality in the Meadowlands of New Jersey.

2. Methods and Materials

2.1 Study area

Air quality was continuously monitored at the Meadowlands Research and Restoration Institute (MRRI), New Jersey Sports and Exposition Authority (NJSEA), located at 2 Dekorte Park

Plaza, Lyndhurst, New Jersey (40° 47’ 08.26” N, 74° 06’ 11.94” W), and about 8 miles north of Newark, NJ (Figure 1). The parameters measured were CO_2, CO, NO_x, ground level ozone, and SO_2. The prevailing winds are from the southwest in the summer and from the northwest in the winter.

Figure 1. The location of the study site.

2.2 Study period

We studied the air quality data at the study site from September 2022 to December 2023. Because of system maintenance and calibration, we didn’t get CO data for October and November 2023. For NOx gas analyzer, the system needed a repair service and maintenance and calibration, so we only get reliable data in April 2023 and from July to November 2023.

2.3 Sampling and analysis method

Air samples were captured by a vacuum pump connected to an air hose and filtered with Whatman 5 µm pore size 47 mm diameter Teflon filters to remove large particulate matter. The air was then pumped into the instruments from inlets through separate plastic tubes (Roberts-Semple et al., 2012). The gas analyzers were operated at room temperature. A data acquisition system (Envidas) (DR DAS LTD, USA), was used for gas analyzer calibration and data management. Every five minutes, the air sample was measured, and the results were added to the database.

Carbon dioxide (CO_2) was analyzed by a Thermo Scientific gas analyzer 410i. The CO level in the air was monitored by Thermo Scientific gas analyzer 48i-TLE and by CO absorption of infrared radiation at a wavelength of 4.6 microns. The Model 48i-TLE uses an exact calibration curve to accurately linearize the instrument output over a wide range of concentrations. NO_x was analyzed by Thermo Scientific gas analyzer 42i and by chemiluminescence. Ozone (O_3) was measured by a Thermo Scientific gas analyzer 49i which uses UV Photometric technology to analyze the amount of ozone in the air from ppb levels up to 200 ppm. Sulfur dioxide (SO_2) was analyzed by Thermo Scientific gas analyzer 43i using pulsed fluorescence technology for the concentration in the air up to 10ppm.

The meteorology data, including temperature, wind speed, wind direction, relative humidity (RH), solar radiation (SR), precipitation, and atmospheric pressure, was collected by MERI weather station (Campbell Scientific) which is part of New Jersey Weather Network and co-located with the gas analyzers. The network used for data sharing is Mesonet.

2.4 Statistical analysis

Parametric and non-parametric tests were used to determine differences between each month. Specifically, we used the analysis of variance (ANOVA) and the Wilcoxon non-parametric tests. Linear Regression Analysis was used to explore the relationship between the gas phase air pollutants. The significance level for all tests was set to $p < 0.05$ and the corresponding confidence level was higher than 95%.

3. Results and discussion

3.1 Carbon dioxide

Carbon dioxide is a natural greenhouse gas produced by respiration and from burning carbon and organic compounds. It is naturally present in the earth’s atmosphere and is absorbed by plants and microorganisms during the photosynthesis process. The pre-industrial level of CO_2 in the atmosphere was less than 0.03% (about 280 ppm) (Eggleton and Eggleton, 2013). The current global CO_2 level is about 0.04% (418 ppm) (NOAA, 2022). Our measuring station is close to a heavy-traffic highway, and therefore, the CO_2 level at this location could be higher than the global CO_2 level.

Figure 2 shows the monthly average of CO_2 concentrations at the study site over a period of one year. The data reveals that the CO_2 level at the study site remained stable at 369 ± 55 ppm. This stability may be attributed to the increasing adoption of electric cars and green energy initiatives in New Jersey.

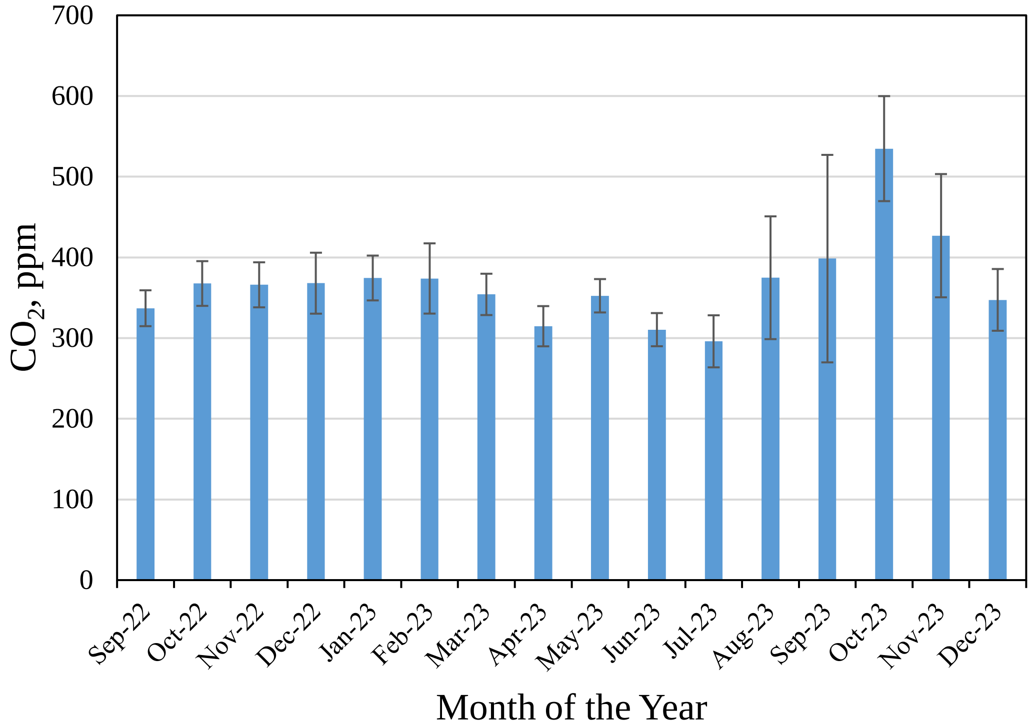

Figure 2. The monthly average CO_2 concentrations from September 2022 to December 2023.

3.2 Carbon monoxide

Based on national ambient air quality standards (NAAQS), carbon monoxide is one of the six “criteria” air pollutants, which includes carbon monoxide, lead, nitrogen oxides, ground-level ozone, particulate matter, and sulfur oxides (EPA, 2015b). Carbon monoxide is a colorless, odorless, and tasteless gas produced by the incomplete combustion of gasoline, wood, propane, charcoal, or other fuels. The largest anthropogenic source of ambient CO in the United States is vehicle emissions, including cars, trucks, and other machinery with internal combustion engines (EPA, 2020). Therefore, ambient CO levels are closely correlated with transportation and industry activities.

Figure 3 illustrates the CO concentration changes at the study site from September 2022 to September 2023. The ambient CO concentrations from 2022 to 2023 were between 2-8 ppm. Our CO concentration level is lower than the National Ambient Air Quality Standards (NAAQS) primary eight-hour (9 ppm) and one-hour standards (35 ppm).

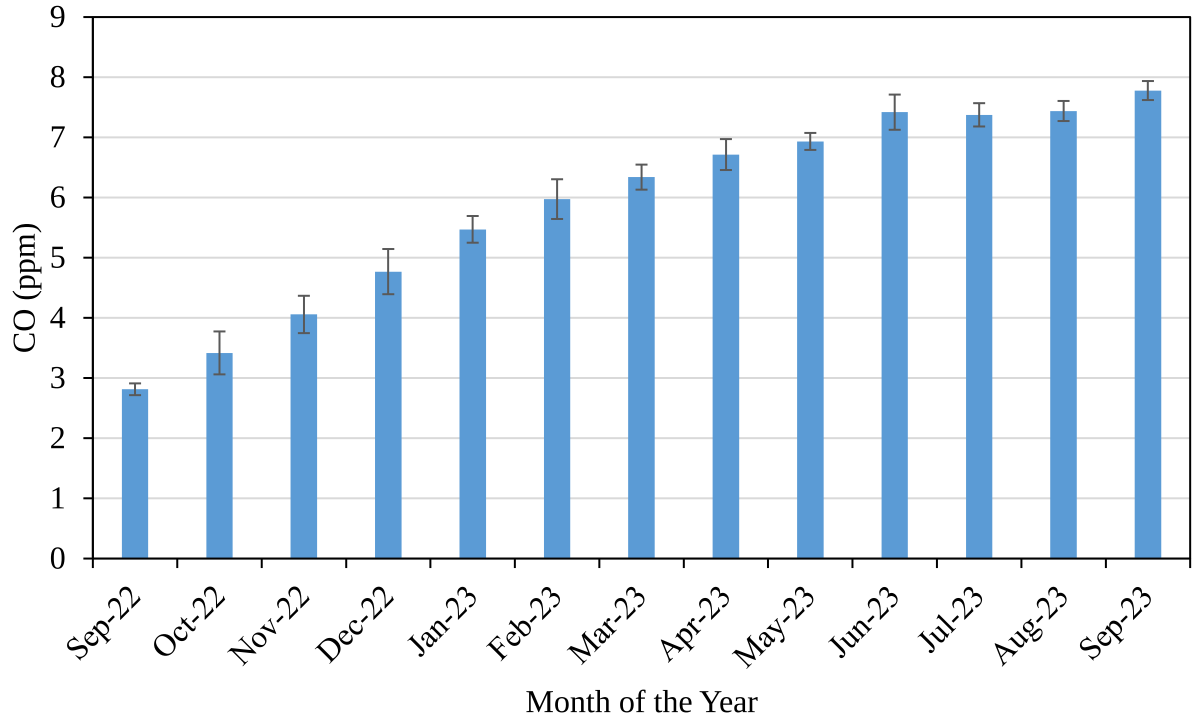

Figure 3. The monthly average CO concentrations from September 2022 to September 2023.

3.3 Nitrogen oxides

Nitrogen oxides (NO_x) are formed by the reaction of oxygen and nitrogen during combustion at high temperatures. Combustion of all kinds of fuel, such as diesel, gas, oil, or organic matter, can generate NO_x (EPA, 1999). NO_x includes seven compounds, such as nitric oxide (NO) and nitrogen dioxide (NO_2). EPA regulates only NO_2 as a surrogate (EPA, 1999). NO_x reacts with ammonium, water vapor and other compounds in the atmosphere and forms nitric acid and small particles which causes acid rain. Through photochemical reactions, NO_x reacts with volatile organic compounds in the presence of sunlight and forms ground-level ozone that harms ecosystems, animal and plant life. NO_x also easily reacts with common organic compounds, and even ozone, to form a variety of toxic products (EPA, 1999).

NO_x emissions in North New Jersey are mainly from transportation system and power plants. New Jersey's busy highways, Port Newark, International airport, power plants, and industrial activities are all sources of NO_x. Figure 4 shows the monthly average of NO_x concentrations from January 2023 to December 2023. Comparing to CO_2 and CO, larger standard deviations were observed for NO_x concentrations. NOx gas analyzer had some major maintenance service during 2023, so several months of data is not available. EPA's NAAQS 1-hour NO_2 standard is 100 ppb and the annual average NO_2 standard is 53 ppb. Therefore, the ambient NO_2 in the Meadowlands District is mostly under the 'Good' air quality range.

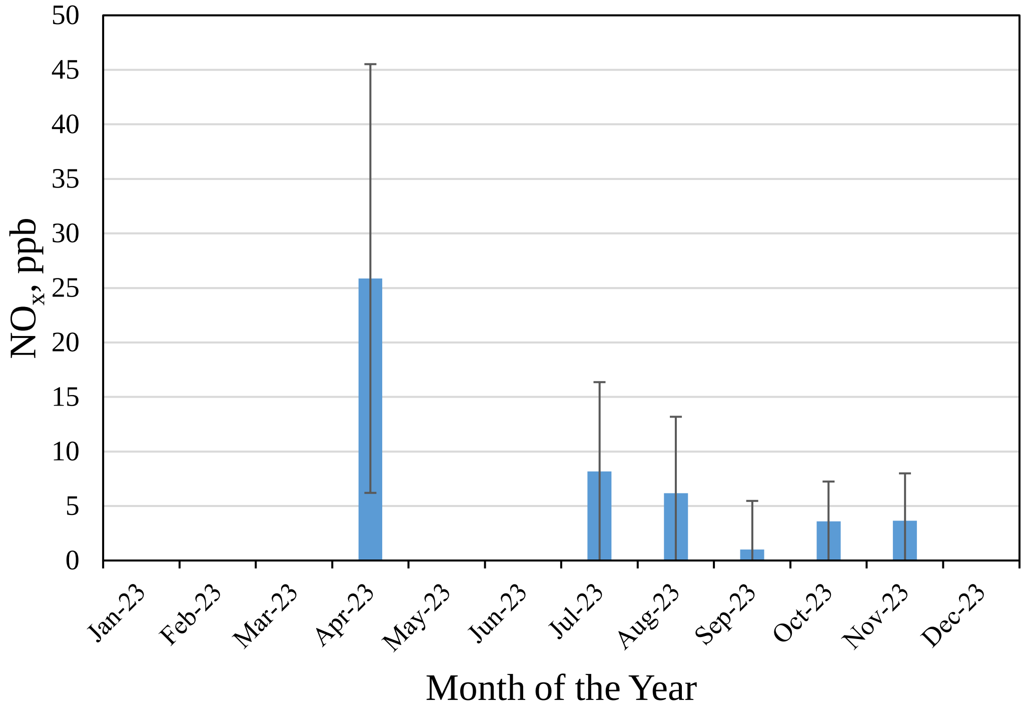

Figure 4. The monthly average of NO_x concentrations from January 2023 to December 2023.

3.4 Ground-level ozone

Ground-level ozone is a "secondary" air pollutant which is formed by NO_x reacting with volatile organic compounds (VOCs) under sunlight and in stagnant air. Therefore, ground level ozone concentration usually varies inversely with NO_x and VOCs and regularly increases with solar radiation and temperature (Sillman et al., 1990). Ozone concentration is proportionally related to VOCs, NO_x, and Solar radiation (Song et al., 2011). Figure 5 shows the monthly average of O_3 concentrations from September 2022 to December 2023. The O_3 concentration levels are higher during the summer and lower during the winter in the Meadowlands of New Jersey. Because the O_3 concentration is highly related with VOCs, NO_x, and Solar radiation, the concentration variation of O_3 is large as well. NAAQS standard for ambient ground-level ozone (8-hour average) is 70 ppb, and the ozone concentration level in the Meadowlands District is lower than the criteria.

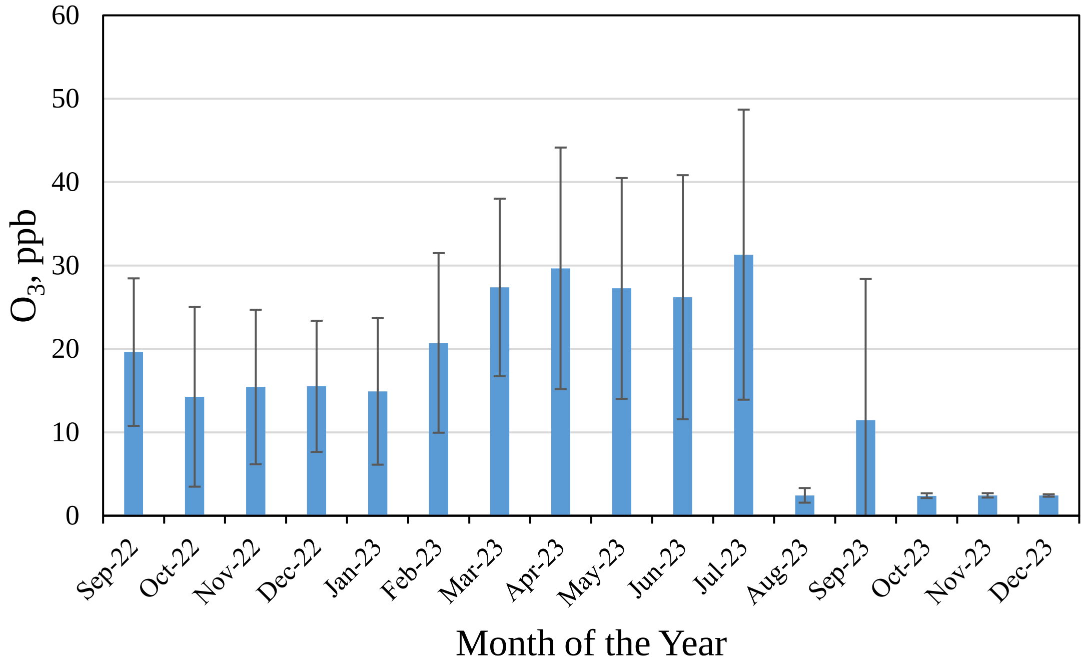

Figure 5. The monthly average of O_3 concentrations from September 2022 to December 2022.

3.5 Sulfur dioxides

Sulfur dioxides (SO_2) is one of the greatest concerns in the ambient gas pollutants, and it is used as the indicator for the larger group of gaseous sulfur oxides (SO_x) (EPA, 2022). Emissions that lead to high concentrations of SO_2 generally also contribute to the formation of other SO_x. The largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities. Control measures that reduce SO_2 can generally be expected to reduce people's exposures to all gaseous SO_x. This may have the important co-benefit of reducing the formation of particulate sulfur pollutants, such as fine sulfate particles. Short-term exposures to SO_2 can harm the human respiratory system and make breathing difficult. People with asthma, particularly children, are sensitive to these effects of SO_2. SO_2 can harm trees and plants by damaging foliage and decreasing growth and can also contribute to acid rain to affect the whole ecosystem (EPA, 2022).

Figure 6 shows the monthly average of SO_2 concentrations from September 2022 to December 2023. EPA's NAAQS 1-hour SO_2 standard is 75 ppb. The SO_2 ambient level is much lower than the NAAQS standard.

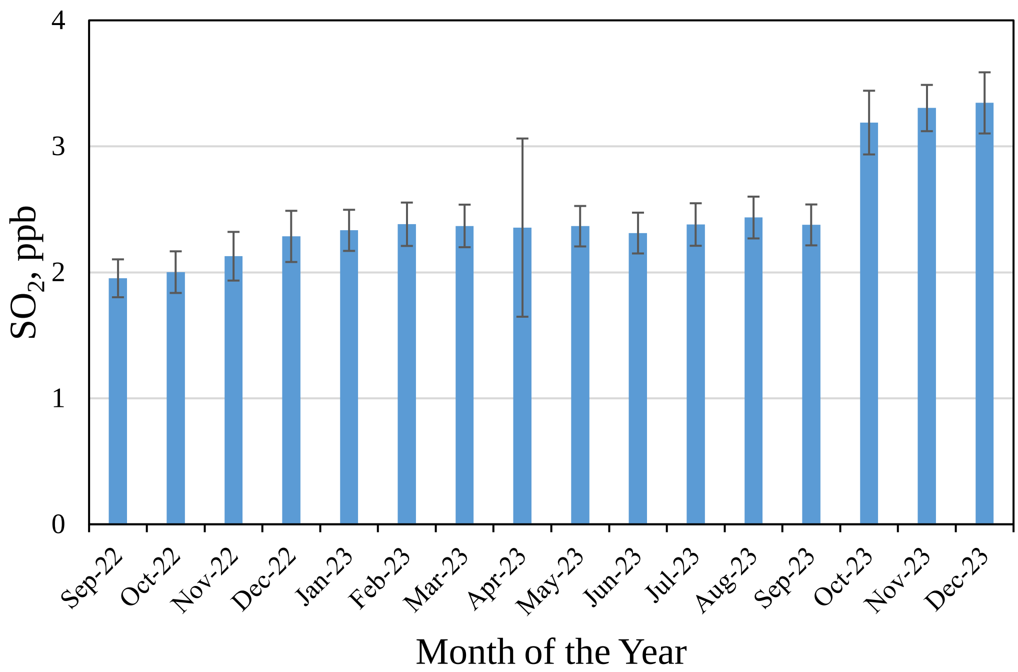

Figure 6. The monthly average of SO_2 concentrations from September 2022 to December 2023.

3.6 Effects of meteorological parameters

The meteorology parameters (i.e. air temperature, relative humidity, solar radiation, wind speed, and precipitation) affect the ambient gas phase air pollutants (i.e. CO_2, CO, NO_x, O_3, and SO_2) concentration levels, so MRRI keeps monitoring the meteorology parameters. With increased temperature, the CO_2 concentration decreased, and the O_3 concentration increased. The seasonal pattern of CO_2 change with temperature change. With increased relative humidity, ozone concentration decreased; with increased solar radiation levels, ozone concentration increased. With a higher wind speed, the concentrations of CO_2, CO, NO_x, and SO_2. were lower. However, the O_3 concentration was higher at a higher wind speed which is similar to the data reported by Roberts-Semple et al. (2012) and Ainslie and Steyn (2007). Our study site was located downwind of busy highways, and the prevailing southwestern winds could bring in the high concentrations of pollutants from that direction (Roberts-Semple et al., 2012). High precipitation rates resulted in relatively low concentrations of CO_2, CO, NO_x, O_3, and SO_2, indicating the washout effect of precipitation (Jiménez-Guerrero et al., 2012). In addition, CO_2 and CO slightly decreased when the solar radiation increased, which could be caused by the seasonal effects (Elbayoumi et al., 2014; Järvi et al., 2012; Roberts-Semple et al., 2012).

4. Conclusion

Based on one-year monitoring and observation, all the gas phase air pollutants are lower than the EPA's NAAQS standards, and the air quality in the Meadowlands District is under the

'Good' category. With the heavy traffic congestion coming back to the area and increased business activities, CO and SO_2 slightly increased. But CO_2 and NO_x levels are still remained at the similar levels as the previous year, which could also be contributed by utilizing more electrical cars and green energies.

Acknowledgments

This study was supported by the Meadowlands Research and Restoration Institute (MRRI), the New Jersey Sports and Exposition Authority (NJSEA). Dr Francisco Artigas leaded and advised this project. Cheryl Yao conducted the data analysis and summery. Joseph Grzyb provided the weather station data. Chris Evangelista maintained the data sharing network. Inputs from Brian Wlodawski, Ildiko Pechmann, and Sandy Speers are also appreciated.

References

Ainslie, B., D.G. Steyn, 2007. Spatiotemporal Trends in Episodic Ozone Pollution in the Lower Fraser Valley, British Columbia, in Relation to Mesoscale Atmospheric Circulation Patterns and Emissions %J Journal of Applied Meteorology and Climatology. 46, 1631-1644.

Eggleton, T., R.A. Eggleton, 2013. A Short Introduction to Climate Change. Cambridge University Press.

Elbayoumi, M., N.A. Ramli, N.F.F. Md Yusof, W.A. Madhoun, 2014. The effect of seasonal variation on indoor and outdoor carbon monoxide concentrations in Eastern Mediterranean climate. Atmospheric Pollution Research 5, 315-324.

EPA, 1999. Nitrogen Oxides (NOx), Why and How They Are Controlled, https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf.

EPA, 2015a. Criteria Air Pollutants, https://www.epa.gov/sites/production/files/2015-10/documents/ace3_criteria_air_pollutants.pdf.

EPA, 2015b. https://www.epa.gov/criteria-air-pollutants/naaqs-table, accessed in July 27, 2020.

EPA, 2020. https://www.epa.gov/co-pollution, accessed in July 27, 2020.

EPA, 2022. https://www.epa.gov/so2-pollution/sulfur-dioxide-basics, accessed in December, 15, 2022.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp,

Järvi, L., A. Nordbo, H. Junninen, A. Riikonen, J. Moilanen, E. Nikinmaa, T. Vesala, 2012. Seasonal and annual variation of carbon dioxide surface fluxes in Helsinki, Finland, in 2006-2010. Atmospheric Chemistry and Physics 12, 8475.

Jiménez-Guerrero, P., J.P. Montávez, J.J. Gómez-Navarro, S. Jerez, R. Lorente-Plazas, 2012. Impacts of climate change on ground level gas-phase pollutants and aerosols in the Iberian Peninsula for the late XXI century. Atmospheric Environment 55, 483-495.

NOAA, 2022. https://gml.noaa.gov/ccgg/trends/, accessed in December 15, 2022.

RGGI, 2020. RGGI Strategic Funding Plan: Years 2020 through 2022, https://nj.gov/rggi/docs/rggi-strategic-funding-plan.pdf

Roberts-Semple, D., F. Song, Y. Gao, 2012. Seasonal characteristics of ambient nitrogen oxides and ground–level ozone in metropolitan northeastern New Jersey. Atmospheric Pollution Research 3, 247-257.

Sillman, S., J.A. Logan, S.C. Wofsy, 1990. The sensitivity of ozone to nitrogen oxides and hydrocarbons in regional ozone episodes. Journal of Geophysical Research: Atmospheres 95, 1837-1851.

Song, F., J. Young Shin, R. Jusino‐Atresino, Y. Gao, 2011. Relationships among the springtime ground–level NOx, O3 and NO3 in the vicinity of highways in the US East Coast. Atmospheric Pollution Research 2, 374-383.

State of New Jersey, 2007. Executive Order #54, in: Corzine, G.J.S. (Ed.).