Air Quality in the Meadowlands of New Jersey
July 2021-June 2022 Report
December, 2022

1. Introduction

The area that includes the coastal marshlands of the meadowlands of New Jersey are located close to the city of Newark and New York City, and it is a reference air quality-monitoring site for regional air quality. The air quality around the New Jersey meadowlands is a concern because of the high population density and heavy industrial infrastructure. The Nearby city of Newark 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 known for its poor air quality from its close to the Port of Newark, Newark International Airport, several energy generating stations, the NJ Turnpike, Route 1&9, one of the largest incinerator in the east coast and one of the largest sewage treatment facilities in the east coast (Passaic Valley Sewerage Commission, PVSC).

In 2007, by Executive Order #54 (State of New Jersey, 2007) the state of New Jersey set a goal to reduce greenhouse gas emissions to 80% below 2006 levels by 2050. 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).

This long-term air quality-monitoring program in the Meadowlands is designed to monitor greenhouse gas emissions and common air pollutants. This program is necessary to verify the effects of future introductions of massive clean and renewable energy sources and the effects it may have to this regional air quality reference area.

2. Methods and Materials

2.1 Study area

Air quality is 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 the City of Newark, NJ (Figure 1). The parameters measured are 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).

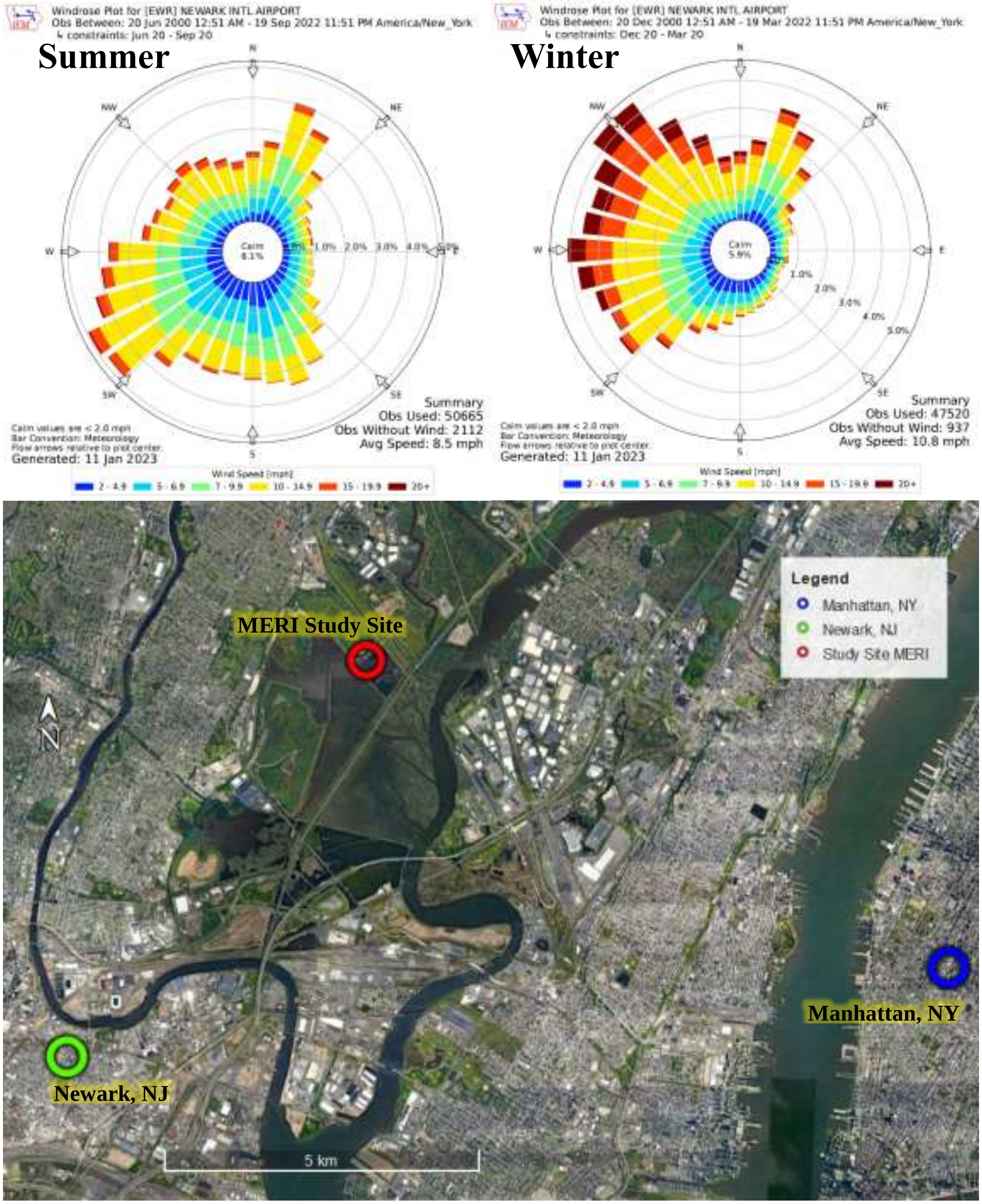

Figure 1. The location of the study site and the prevailing winds during the summer and winter.

2.2 Study period

This study period reports on the air quality from July 2021 to June 2022. Because of system maintenance and software upgrade, data for April and May 2022 is missing. Due to sensor failures, data for NOx between April 2022 to June 2022 was not collected.

2.3 Sampling and analysis method

The intake air sample is located on the roof of the second floor of the Dekorte Park Plaza Environmental Center. 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 operate 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 is sampled and 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, is 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 are used to determine differences in concentration between each month. Specifically, we used the analysis of variance (ANOVA) and the Wilcoxon non-parametric tests. Linear Regression Analysis is used to explore the relationships 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 influenced by close proximity to a heavy traffic highway and can be slightly higher than the global CO_2 level.

Figure 2 shows the monthly average of CO_2 concentrations during the one-year study period. During the study period, CO_2 levels showed a slight decreasing trend. This pattern can be attributed to several reasons: 1) The COVID-19 effect: more people have chosen to work from home and to buy on-line which results in less fossil fuels emissions. 2) A surge in electric cars and green energy sources.

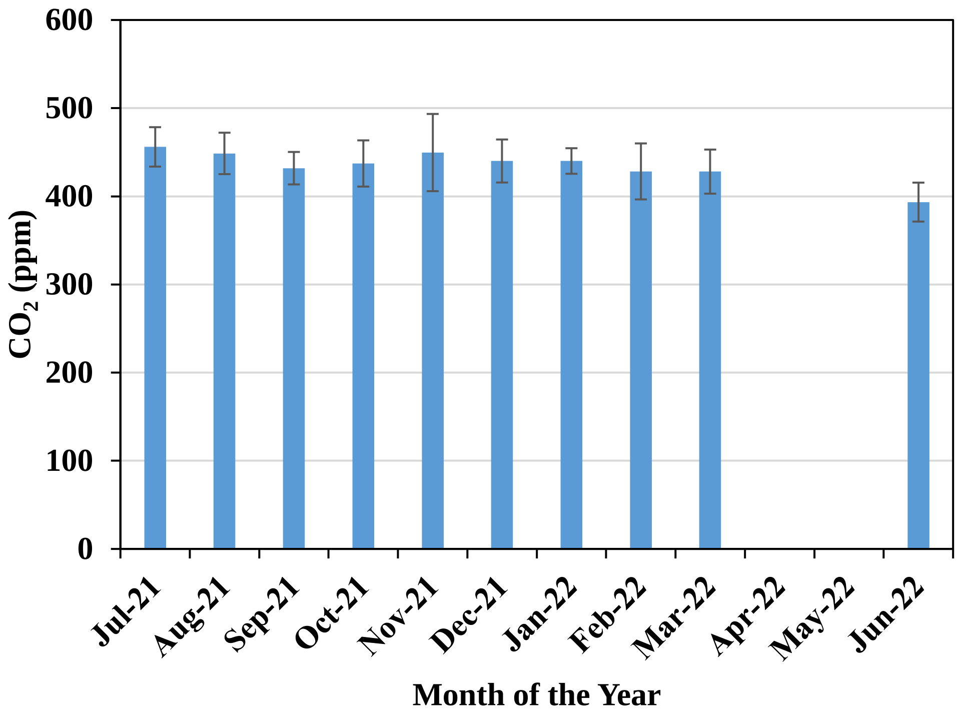

Figure 2. The monthly average of CO_2 concentrations from July 2021 to June 2022.

3.2 Carbon monoxide

Based on national ambient air quality standards (NAAQS), carbon monoxide is one of the six “criteria” air pollutants (i.e. 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). Ambient CO levels are closely correlated with transportation and industry activities.

Figure 3 illustrates the CO concentration changes at the study site from July 2021 to June 2022. The ambient CO concentration increased from 2021 to 2022. The observed increase can be explained by increased use of fossil fuel sources for home heating during the winter months and a rebound of industrial activity after the Pandemic period. However, the CO concentration levels are still lower than the National Ambient Air Quality Standards (NAAQS) primary eight-hour (9 ppm) and one-hour standards (35 ppm).

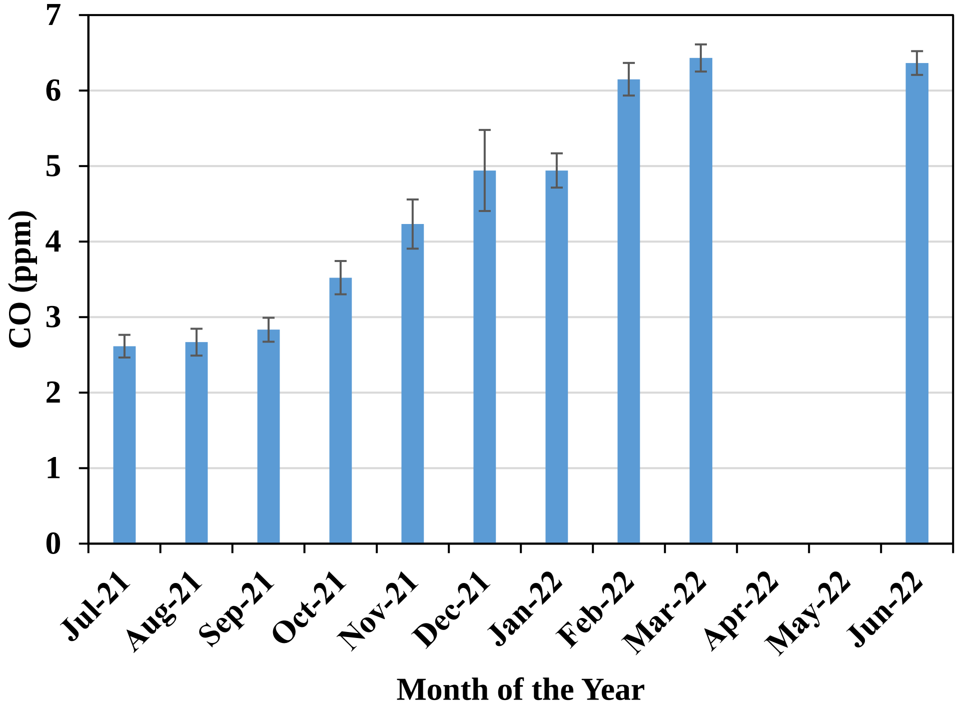

Figure 3. The monthly average of CO concentrations from July 2021 to July 2022.

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 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 that causes acid rain. Through photochemical reactions, NO_x reacts with volatile organic compounds in the presence of sunlight and forms ground-level ozone harmful to 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 July 2021 to March 2022. Comparing to CO_2 and CO, larger standard deviations were observed for NO_x. 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.

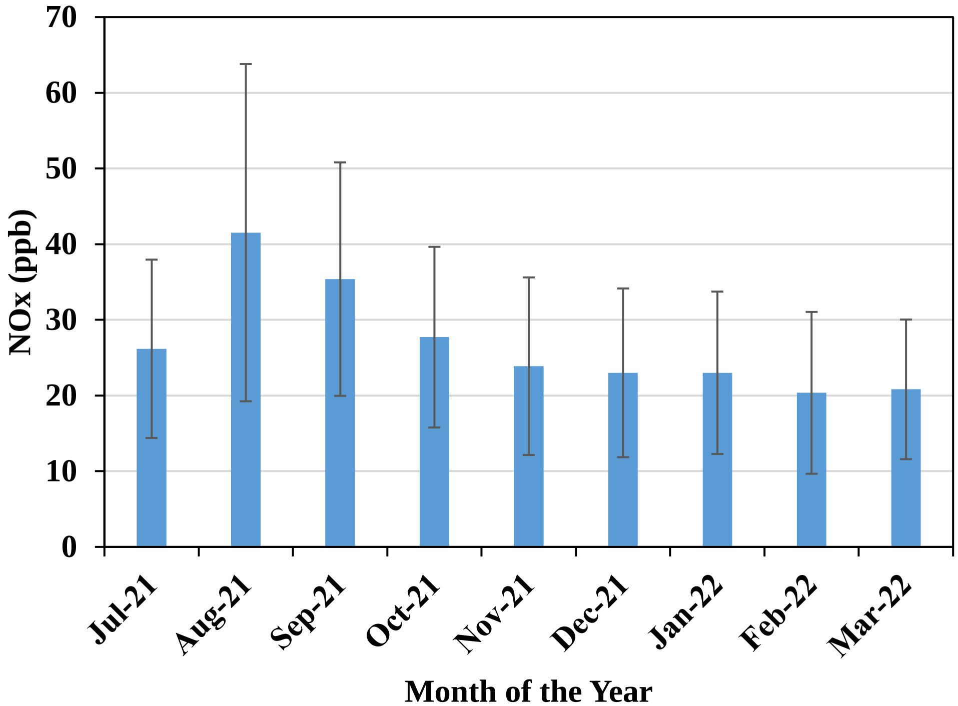

Figure 4. The monthly average of NO_x concentrations from July 2021 to March 2022.

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. 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 July 2021 to June 2022. Ozone concentrations in our area show a direct correlation with air temperature. NAAQS standard for ambient ground-level ozone (8-hour average) is 70 ppb. The ozone concentration level in the Meadowlands District is lower than the criteria.

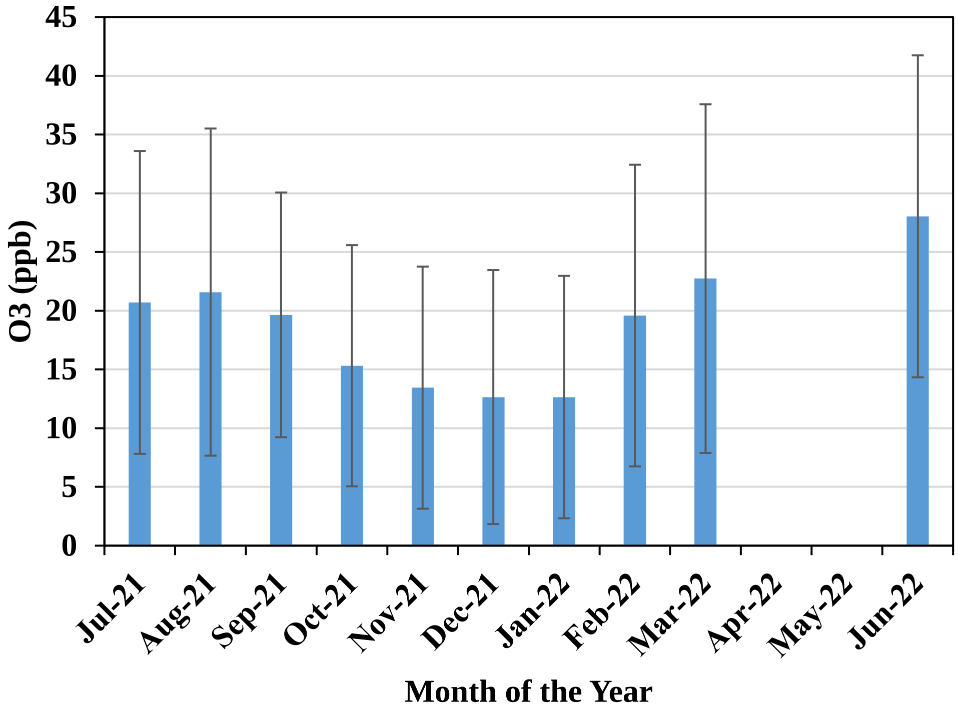

Figure 5. The monthly average of O_3 concentrations from July 2021 to June 2022.

3.5 Sulfur dioxides

Sulfur dioxides (SO_2) is one of the greatest concerns among 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 the effects of SO_2. SO_2 derived acid rain can harm trees and plants by damaging foliage and decreasing growth rates of forests (EPA, 2022).

Figure 6 shows the monthly average of SO_2 concentrations from July 2021 to June 2022. EPA's NAAQS 1-hour SO_2 standard is 75 ppb. The SO_2 ambient level in the District is much lower than the NAAQS standard.

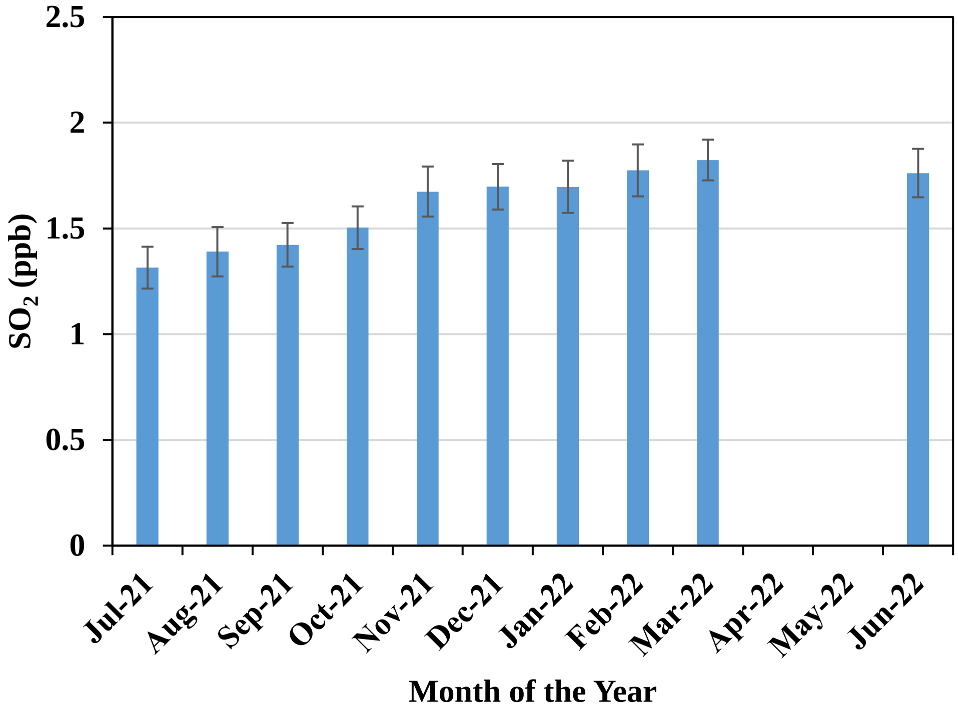

Figure 6. The monthly average of SO_2 concentrations from July 2021 to June 2022.

3.6 Effects of meteorological parameters

Monitoring meteorology parameters such as air temperature, relative humidity, solar radiation, wind speed, and precipitation is important because these have an effect on the ambient gas phase levels of air pollutants such as CO_2, CO, NO_x, O_3, and SO_2. CO_2 concentration decreased with increases in temperatures. Ozone concentration increased with increases in relative humidity, solar radiation and temperature. Higher wind speeds resulted in lower concentrations of CO_2, CO, NO_x, and SO_2. Ozone concentration was higher with increased wind speed and similar to the data reported by Roberts-Semple et al. (2012) and Ainslie and Steyn (2007). When southwestern winds prevail, our study area is located downwind from busy highways and industrial centers (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, and due to seasonal effects CO_2 and CO slightly decreased when the solar radiation increased (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. However, CO_2 and NO_x levels did not increase significantly and remained at levels similar to the previous year. This may be indicating that changes in human behavior and the introduction of renewable sources of energy are starting to have an effect on the regional air quality.

Acknowledgments

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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, Summary for Policymakers, https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

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.